PERIODICAL

#6

ASSOCIATION D'OCEANOGRAPHIE PHYSIQUE

Union Géodésique et Géophysique Internationale

#6

PROCES-VERBAUX No 6

GENERAL ASSEMBLY

at

ROME

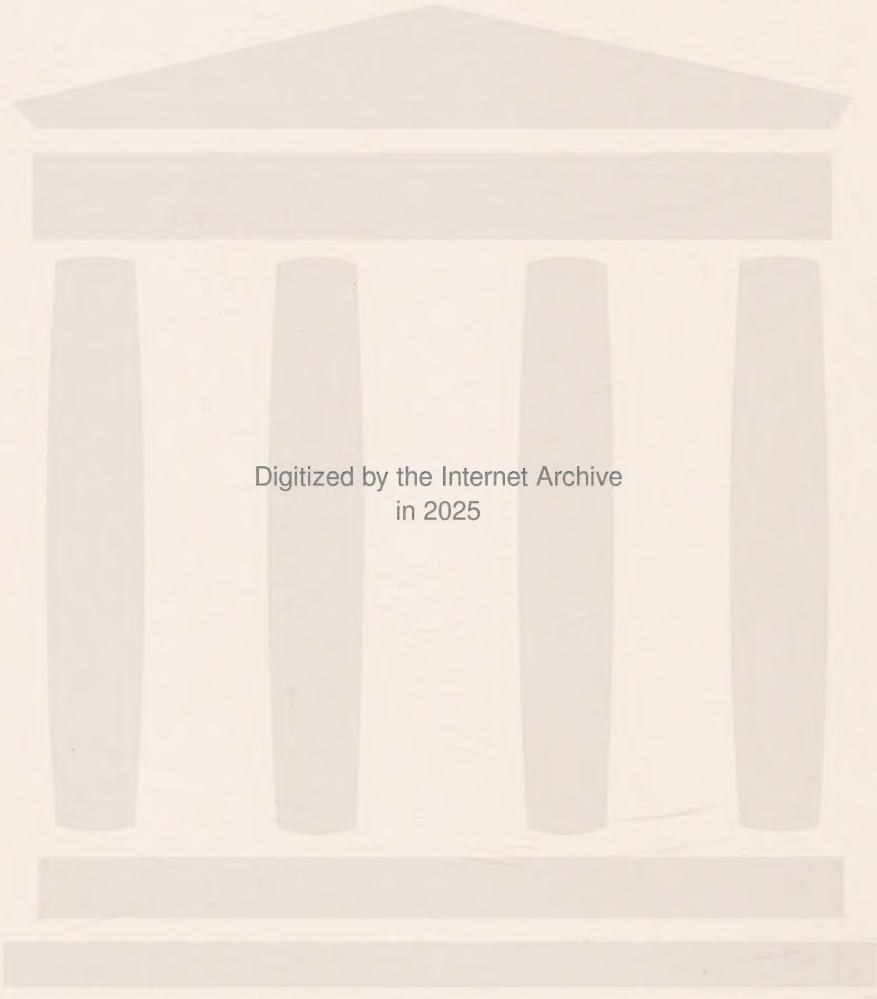
September 1954

Published with financial assistance from UNESCO

Price 30 Shillings

1954

Secrétariat de l'Association: Geofysisk Institut, Bergen, Norway



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ASSOCIATION D'OCEANOGRAPHIE PHYSIQUE

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Printed March 1955.

A.S John Griegs Boktrykkeri, Bergen.

The General Assembly of the
Association was held on the occasion
of the Tenth General Assembly of the Union.
The meetings of the Association were held in the
Palace of Congresses of the Organisation
«EUR», World Fair of Rome from the
14th to the 25th September 1954

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OFFICERS AND EXECUTIVE COMMITTEE

(1951—54)

PRESIDENT:	Professor Dr. J. PROUDMAN, The University, Liverpool 3, England.
VICE-PRESIDENTS:	1) Dr. C. O'D. ISELIN, Woods Hole Oceanographic Institution, Mass., U.S.A. 2) Capitaine J. ROUCH, Musée Océanographique, Monaco.
SECRETARY:	Professor Dr. H. MOSBY, Geofysisk Institutt, Universitetet, Bergen, Norway.
DEPUTY SECRETARY:	Dr. R. H. FLEMING, University of Washington, Seattle 5, Wash., U.S.A.
MEMBERS:	Dr. J. N. CARRUTHERS, Great Britain. Prof. Dr. H. PETTERSSON, Sweden. Prof. Dr. P. GROEN, Netherlands. Prof. Dr. H. U. SVERDRUP, Norway.

STANDARD SEA WATER SERVICE

(1951—54)

In charge:	Mr. H. THOMSEN, Charlottenlund slot, Copenhagen.

SCIENTIFIC COMMITTEES

(1951—54)

COMMITTEE ON TIDES

Chairman:	H. A. MARMER[1].
Secretary:	J. PROUDMAN.
Members:	J. E. FJELDSTAD, A. GOUGENHEIM, W. HORN, N. MENENDEZ, M. TENANI.

COMMITTEE ON MEAN SEA-LEVEL AND ITS VARIATIONS

Chairman:	J. D. NARES.
Secretary:	R. H. CORKAN[2].
Members:	L. P. DISNEY, J. EGEDAL.

COMMITTEE ON NOMENCLATURE OF OCEAN BOTTOM FEATURES

Chairman:	J. D. H. WISEMAN.
Secretary:	J. D. NARES.
Members:	K. O. EMERY, H. H. HESS, Ph. H. KUENEN, H. PETTERSSON.

COMMITTEE ON OCEANOGRAPHICAL OBSERVATIONS FROM ATLANTIC WEATHER SHIPS

Chairman:	J. R. LUMBY.
Secretary:	H. MOSBY.
Members:	J. LE GALL[3], J. LYMAN, F. S. RUSSELL, J. W. TERMIJTELEN, H. THOMSEN.

[1] died on 5th November 1953, replaced by J. PROUDMAN.
[2] died on 12th February 1952, replaced by A. T. DODSON.
[3] died on 5th February 1954.

COMMITTEE ON PREPARATION OF TECHNICAL HANDBOOK ON PHYSICAL OCEANOGRAPHY

Chairman:	H. U. Sverdrup.
Members:	J. N. Carruthers, G. E. R. Deacon, E. C. LaFond, H. Mosby, N. W. Rakestraw.

COMMITTEE ON QUESTIONS CONCERNING PREPARATION OF A BIBLIOGRAPHY

Chairman:	H. U. Sverdrup.
Secretary:	P. Groen.
Members:	H. L. G. Bencker, J. N. Carruthers, L. Fage, J. R. Lumby, R. B. Montgomery, R. Revelle, J. T. Ruud, F. Vercelli[1].

JOINT COMMISSION ON OCEANOGRAPHY

(June 1954).

Members appointed by IUGG:	J. D. H. Wiseman (president), C. W. Correns, M. Ewing, Ph. H. Kuenen, H. Mosby, H. Pettersson.
Members appointed: by IUBS:	A. F. Bruun, L. Fage, R. Revelle. Mary Sears.
Secretary:	C. D. Ovey.
Advisory councillors:	F. Bernard, F. Koczy, J. D. Nares, J. Rouch, H. U. Sverdrup, H. C. Urey, C. E. Zobell.

[1] died on 24th November 1952.

OFFICERS AND EXECUTIVE COMMITTEE

Appointed by General Assembly at Rome, September 1954.

PRESIDENT: Professor Dr. H. MOSBY, Geofysisk Institutt, Universitetet, Bergen, Norway.

VICE-PRESIDENTS: 1) Dr. J. N. CARRUTHERS, National Institute of Oceanography, Wormley, Near Godalming, Surrey, Great Britain.
2) Capitaine J. ROUCH, Musée Océanographique, Monaco.

SECRETARY: Professor Dr. R. H. FLEMING, University of Washington, Seattle 5, Wash., U.S.A.

DEPUTY SECRETARY: Dr. B. KULLENBERG, Oceanografiska Institutet, Stigbergstorget 8, Göteborg, Sweden.

MEMBERS: Prof. Dr. P. GROEN, Netherlands.
Prof. Dr. H. U. SVERDRUP, Norway.
Dr. G. BÖHNECKE, Germany.
Prof. Dr. J. PROUDMAN, Great Britain.

STANDARD SEA-WATER SERVICE

1954—57

In charge: Mr. H. THOMSEN, Charlottenlund slot, Copenhagen.

SCIENTIFIC COMMITTEES

Appointed by General Assembly at Rome, September 1954

COMMITTEE ON TIDES

Chairman: J. Proudman.
Secretary: A. Gougenheim.
Members: L. P. Disney, J. E. Fjeldstad, K. Hidaka, W. Horn, N. Menendez, J. B. Schijf, M. Tenani,

COMMITTEE ON MEAN SEA-LEVEL AND ITS VARIATIONS

Chairman: J. D. Nares.
Secretary: A. T. Doodson.
Member: L. P. Disney.

COMMITTEE ON NOMENCLATURE OF OCEAN BOTTOM FEATURES

Chairman: J. D. H. Wiseman.
Secretary: J. D. Nares.
Members: A. F. Bruun, K. O. Emery, H. H. Hess, F. Koczy, Ph. H. Kuenen, T. Stocks.

COMMITTEE ON OCEANOGRAPHICAL OBSERVATIONS FROM ATLANTIC WEATHER SHIPS

Chairman: J. R. Lumby.
Secretary: O. H. Sælen.
Members: A. Gougenheim, J. Lyman, K. M. Rae, J. W. Termijtelen, H. Thomsen.

COMMITTEE ON PREPARATION OF TECHNICAL HANDBOOK ON PHYSICAL OCEANOGRAPHY

Chairman:	H. U. Sverdrup.
Members:	G. Böhnecke, J. N. Carruthers, G. E. R. Deacon, A. Gougenheim, E. C. Lafond, H. Mosby, N. W. Rakestraw.

COMMITTEE ON QUESTIONS CONCERNING PREPARATION OF A BIBLIOGRAPHY

Chairman:	H. U. Sverdrup.
Secretary:	P. Groen.
Members:	H. L. G. Bencker, J. N. Carruthers, L. Fage, J. R. Lumby, R. B. Montgomery, R. Revelle, J. T. Ruud.

COMMITTEE ON THE GEOPHYSICAL YEAR 1957—58

Chairman:	R. H. Fleming.
Secretary:	G. E. R. Deacon.
Members:	G. Böhnecke, A. Defant, A. Gougenheim, M.S. Longuet-Higgins, J. Lyman, W. Munk.

COMMITTEE ON STORM SURGES

Chairman:	A. T. Doodson.
Secretary:	J. B. Schijf.
Members:	L. P. Disney, W. Horn.

COMMITTEE ON CURRENT MEASUREMENTS

Chairman:	G. Böhnecke.
Secretary:	W. S. von Arx.
Members:	J. N. Carruthers, J. E. Fjeldstad, H. Mosby, V. Romanovsky

JOINT COMMISSION ON OCEANOGRAPHY

Members appointed by IUGG: (*Rome, Sept. 1954*)	J. D. H. Wiseman (President), C. W. Correns, M. Ewing, Ph. H. Kuenen, R. H. Fleming, H. Pettersson.
Members appointed by IUBS:	A. F. Bruun, L. Fage, R. Revelle, Mary Sears.
Secretary:	C. D. Ovey.
Advisory Councillors:	F. Bernhard, E. Bullard, L. H. N. Cooper, G. E. R. Deacon, A. Defant, C. Fleming, M. N. Hill, F. Koczy, Th. Monod, J. D. Nares, J. Rouch, H. U. Sverdrup, H. C. Urey, C. E. Zobell.

TERMS OF REFERENCE OF SCIENTIFIC COMMITTEES

Committee on Tides: To prepare a bibliography of publications for the years subsequent to 1939.

Committee on Mean Sea-Level and its Variations: To collect and publish monthly and yearly mean values of heights of sea-level.

Committee on Nomenclature of Ocean Bottom Features: To endeavour to establish, in co-operation with chart-making authorities, mechanisms for international agreement on the nomenclature of submarine topographical features. To consider methods for presentation of marine topographical data on bathymetric charts.

Committee on Oceanographical Observations from Atlantic Weather Ships: To encourage each country to undertake systematic physical, chemical, geological and biological observations as their individual facilities and personnel permit. Liaison with the national committees, gradual development of a uniform programme and arrangements for the exchange and for publication of data.

Committee on Preparation of Technical Handbook on Physical Oceanography: To prepare a Handbook dealing with installations on board ships, instruments, work at sea, processing of observations and definition of special oceanographic terms.

Committee on Questions concerning Preparation of a Bibliography: To prepare for presentation to the next meeting of the IAPO a generally acceptable classification scheme of physical oceanographic literature within the framework of the Universal Decimal Classification.

Committee on Geophysical year 1957—58: To consider proposals for oceanographical research in the Geophysical Year 1957—58 and co-ordinate efforts made by different institutions.

Committee on Storm Surges: To act as an editorial committee for data on selected cases of storm surges within a small number of selected regions.

Committee on Current Measurements: To consider the numerous ways, means and methods of performing current measurements at sea, so that an adequate body of guidance may become available.

Joint Commission on Oceanopgraphy: To lay plans for the continuance of the work after 1957 by some other suitable body, consideration being given to what form the future body should take in order to avoid overlapping. (Cf. Report p. 109).

Administrative Reports

REPORT OF THE SECRETARY FOR THE PERIOD 1951—55

One of the members of the Committee on Questions concerning Preparation of a Bibliography, Dr. F. VERCELLI, died on 24th November 1952.

On the death of Dr. H. CORKAN on 12th February 1952 the Executive Committee appointed Dr. A. T. DOODSON as secretary of the Committee on Mean Sea-Level and its Variations for the remaining part of the period.

On the death of Mr. H. A. MARMER on 5th November 1953 the secretary of the Committee on Tides, Dr. J. PROUDMAN, was asked to serve as Chairman of the committee for the remaining part of the period.

One of the members of the Committee on Oceanographical Observations from Atlantic Weather Ships, Dr. J. LE GALL, died on 5th February 1954.

The activities of the Standard Sea Water Service have continued under the conduct of Mr. HELGE THOMSEN (see p. 19).

Since the General Assembly at Brussels the following publications have been issued:

Procès- Verbaux.

No. 5. General Assembly at Brussels, August 1951 (1952).

Publications Scientifiques.

Technical Handbook on Physical Oceanography, Section D, Processing Ashore

was printed by the U.S. Hydrographic Office as

H. O. Pub. No. 614. E. C. LaFond: Processing Oceanographic Data. Washington D. C., 1951.

As agreed at Brussels (Proc. Verb. No. 5, p. 51), this publication was sent to each adhering country in number of copies according to category of membership.

The Committe on Mean Sea-Level and its Variations has prepared a manuscript for

No. 12. Monthly and Annual Heights of Sea-Level, 1947—51

and sent it to the printers.

The Committee on Tides has prepared a

Bibliography on Tides

covering publications from the years 1665 to 1939.

After its reorganization at Brussels in 1951 the Joint Commission on Oceanography has been very active, as seen from its Report (p. 109). Throughout the period the Secretary has been kept informed on these activites.

Håkon Mosby

FINANCIAL REPORT FOR THE PERIOD 1951—54.

A summary statement of Receipts and Payments for the period 1st January 1951 to 31st December 1953 and the Balance Sheet for 31st December 1953 are given in the accompanying tables. This statement, as well as the single accounts for each year have been examined and certified by Aksel Dale, accountant, Bergen, and sent to the Finance Committee of the Union and to the General Secretary, Colonel G. Laclavère.

The separate statement on grants from UNESCO is extracted from the occounts; it will be seen that the total amount of US $ 4.000 corresponds to the total of N. Kr. 28 472.98. An unexpended balance of US $ 70.43 of the allocation to cover travelling expenses for participants at the Symposium was by special permission added to the allocation for printing expenses. An unexpended balance

of US $ 113.58 of the allocation to cover travelling expenses for members of the Committee on Nomenclature of Ocean Bottom Features had to be returned.

Håkon Mosby.

ACCOUNTS FOR THE PERIOD 1st JANUARY 1951 TO 31st DECEMBER 1953

Receipts:

	1951	1952	1953
Allocation from Union ..... N. Kr	16 207.57	16 207.58	16 287.25
Allocation from UNESCO	18 541.17	6 371.22	3 560.59
Sale of publications	30.75	89.40	208.82
Bank interests	418.80	616.35	615.59
	35 198.29	23 284.55	20 672.25

Payments:

	1951	1952	1953
Standard Sea Water Service	5 011.50	5 013.50	5 014.50
Salary St. Sea Water Service	1 251.20	1 258.10	1 252.20
Printing			
Publ. Scient. No. 11	977.00		
Agenda, abstracts	3 786.70		
Proc.-Verb. No. 5, Symposium		8 198.65	
Copies of H. O. Publ. 614		3 753.75	
Travelling			
Participants Symposium	10 221.70		
Officers of the Association	7 187.00		
Members Nomenclature Committee	977.08		
Young scientists	716.46		
Bureau			
Secretarial Assistance	991.86	445.00	1 013.00
Postage, stationery	1 234.93	1 519.38	558.75
Unexp. balance Nomencl. Committee ..			816.46
	32 355.43	20 188.38	8 645.91
Credit.....	2 842.86	3 096.17	12 017.34

BALANCE SHEET AT 31st DECEMBER 1953

Assets 31/12 1950	Kr.	49 899.15
Net credit 1951—53	»	17 956.37
Real assets	Kr.	67 855.52
Debt to Union	»	5 676.92
	Kr.	73 532.44
Cash in Bank and Hand 31/12 1953	Kr.	73 532.44

I have examined the Accounts of the Association of Physical Oceanography for the three years ended 31st December 1953 and hereby certify that the said accounts are in order.

(*Signed*) Aksel Dale (*Accountant*).

BERGEN 7th August 1954.

UNESCO GRANTS FOR THE PERIOD 1st JANUARY 1951 TO 31st OCTOBER 1953.

Receipts:

	1951	1952	1953
Standard Sea Water Service ..... $	500	500	500
Travelling Symposium participants	1 500		
— AIOP officers	250		
— Young scientists	100		
— Nomenclature Committee	250		
Printing Proc.-Verb. No. 5		400	
	2 600	900	500
		Total $	4 000

Payments:

Standard Sea Water Service ..... $	500	500	500
Travelling Symposium participants	1 429.57		
— AIOP officers	250.00		
— Young scientists	100.00		
— Nomenclature Committee	136.42		
Printing of reports		470.43	
Unexpended balance			113.58
	2 415.99	970.43	613.58
			Total $ 4 000

REPORT ON THE STANDARD SEA-WATER SERVICE FOR THE PERIOD JANUARY 1st 1951—DECEMBER 31st 1953

Two batches of Standard Sea-Water were prepared namely
P_{21} sealed on September 9th 1951. Chlorinity 19.379 $^0/_{00}$
3377 tubes were filled.
P_{20} sealed on March 29th 1953, Chlorinity 19.375 $^0/_{00}$
3604 tubes were filled.

The glass tubes used were made in Germany from neutral Glass, which has been found satisfactory as regards solubility and melting point.

During the three year period a total of 6719 tubes of Standard Sea-Water were sold at net price of D. Kr. 2.00 to users in Algiers. Australia, Belgium, Bulgaria, Brazil, Canada, China, Denmark, Finland, France, French Western Africa, Great Britain, Greece, Hong Kong, Iceland, India, Indonesia, Italy, Madagascar, Mauretania, Monaco, Morocco, Netherlands, New-Zealand, Norway, Poland, Portugal, Sierra Leone, South Africa, Spain, Sweden, USA, Yugoslavia and Zanzibar.

The sale exhibits an increasing tendency, as will be noted from the figures of the single years, which were:

1951:	1725 tubes
1952:	2196 «
1953:	2798 «
Total:	6719 tubes

Of this amount, 3800 tubes were sold to the firm G. M. Manufacturing Co. in New York, who stock Standard Sea-Water for users in United States.

Helge Thomsen.

DELEGATES AND GUESTS ATTENDING GENERAL ASSEMBLY

Hamon, B. V.

Defant, A.

Acevedo, A. D.

Hachey, H. B.

Andrade, A.
Ihl, P.

Thomsen, H.

Granqvist, G. J. M.

Bernard, F.
Bourcart, J.
Cahierre, L.
Gerlier, P.
Gougenheim, A.
Julien, A.

Böhnecke, G.
Hansen, W.

Stassinopoulos, A. C.

AUSTRALIA.

AUSTRIA.
Hecht, F.

ARGENTINA.
Capurro, L. R. A.

CANADA.

CHILE.
Saavedra, R. E.

DENMARK.

FINLAND.
Lisitzin, E.

FRANCE.
Le Grand, Y.
Romanovsky, V.
Sauvage de St. Marc, G.
Tchernia, P.
Valembois, J.

GERMANY.
Joseph, J.

GREECE.

Bowden, K. F.
Burling, R. W.
Carruthers, J. N.
Cooper, L. H. N.
Crease, J.
Day, A. A.
Deacon, G. E. R.
Doodson, A. T.
Farquharson, W. I.
Goldsbrough, G. R.
Hill, M. N.
Longuet-Higgins, M. S.
Lumby, J. R.

Neumann, J.

Blanc, A. C.
Girard, M. M.

Roux, G.

Dorrestein, R.
Groen, P.
Santema, P.

Eggvin, J.
Fjeldstad, J. E.
Mosby, H.

Affonso Dias, M.

Balen, F.

Hellstrøm, B.
Jerlov, N.

Castany, G.

GREAT BRITAIN.
Mortimer, C. H.
Ovey, C. D.
Penman, H. L.
Proudman, J.
Rae, K. M.
Rossiter, J. R.
Stagg, J. M.
Sutcliffe, R. C.
Tait, J. B.
Tucker, M. J.
Ursell, F.
Vaux, D.
Wiseman, J. D. H.

ISRAEL.
Shalem, N.

ITALY.
Greco, L.
Tenani, M.

MOROCCO.

NETHERLANDS.
Schijf, J. B.
Thijsse, J. T.

NORWAY.
Sverdrup, H. U.
Sælen, O. H.

PORTUGAL.

SPAIN.
Menéndez, N.

SWEDEN.
Koczy, F.
Pettersson, H.

TUNISIA.

U.S.A.

Dietz, R.
Disney, L. P.
Emery, K. O.
Fleming, R. H.
Freeman, J. C.
Hunt, I. A.
Lyman, J.
Munk, W.
Revelle, R.
Sears, Mary.
Urey, H. C.
Von Arx, W. S.
Wiegel, R. L.

International Hydrographic Bureau.

Nares, J. D.

International Commission for the Scientific Exploration of the Mediterranean.

Malduro, C.
Morandini, G.
Picotti, M.

Panamerican Institute of Geography and History

Simonpietri, A.

GENERAL ASSEMBLY AT ROME
SEPTEMBER 1954.

AGENDA

The items numbered by decimals were not included in the Agenda circulated before the General Assembly.

A. President's Address.

J. Proudman: The Unknown Tides of the Oceans. See pp. 34, 83.

B. Administration.

1. Report of the Secretary for the period 1951—54. pp. 14, 63.
2. Report on the Standard Sea Water Service 1951—54. pp. 19, 63.
3. Financial Report for the period 1951—54. pp. 15, 63.
4. Financial estimates for the next period. pp. 63, 64.
5. Election of the President, Vice-Presidents and two members of the Executive Committee. pp. 8, 64.

C. Reports of Scientific Committees.

1. Committee on tides. pp. 30, 92.
2. Committee on mean sea-level and its variations. pp. 30, 93.
3. Committee on nomenclature of ocean-bottom features. pp. 31, 75, 97.
4. Committee on oceanographical observations from Atlantic weather ships. pp. 31, 62, 98.
5. Committee on preparation of technical handbook on physical oceanography. pp. 31, 64, 100.
6. Committee on questions concerning preparation of a bibliography. pp. 31, 64, 101.

7. Committee on the Geophysical Year 1957—58. pp. 31, 35, 102.
8. Committee on storm surges. pp. 30 (D 2), 75, 105.
9. Committee on current measurements. pp. 64 (D 9), 75, 107.
10. Joint commission on oceanography. pp. 31, 64, 75, 109.

D. Appointment of Scientific Committees.

1. Committee on tides. pp. 9, 30.
2. Committee on mean sea- level and its variations. pp. 9, 30.
3. Committee on nomenclature of ocean-bottom features. pp. 9, 75.
4. Committee on oceanographical observations from Atlantic weather ships. pp. 9, 31.
5. Committee on preparation of technical handbook on physical oceanography. pp. 10, 64.
6. Committee on questions concerning preparation of a bibliography. pp. 10, 64.
7. Committee on the Geophysical Year 1957—58. pp. 10, 31, 32.
8. Committee on storm surges. pp. 10, 30 (D 2), 75.
9. Committee on current measurements. pp. 10, 64.
10. Joint commission on oceanography. pp. 11, 75.

E. National and Institutional Reports.

1. British national report of physical oceanography 1951 to 1954. pp. 76, 111.
2. A review of Canadian oceanography. pp. 76, 121.
3. Physikalische Ozeanographie am Deutschen Hydrographischen Institut 1951—54. pp. 76, 123.
4. Raport sobre los trabajos realizados en España sobre oceanografia fisica desde el año 1951. pp. 76, 131.
5. Oceanography in Finland. pp. 76, 134.
6. Note on recent oceanographic work in India. pp. 76, 136.
7. Tidal work in India. pp. 76, 143.
8. Physical oceanography in Ireland. pp. 76, 146.
9. Oceanography in Texas. pp. 76, 147.
10. Report on work carried out by the Service Hydrographique of the International council for the exploration of the sea, 1951—54. pp. 76, 148.
11. Report on ocean wave research conducted at New York University. pp. 76, 150.

12. Oceanographic program at the University of Washington. pp. 76, 154.
13. Physical oceanography in the Argentine Republic. pp. 76, 155.
14. Philippine national report on physical oceanography. pp. 76, 161.
15. Rapporto sui lavori oceanografici in Italia, eseguiti nel triennio 1951—1954. pp. 76, 163.
16. Il triennio 1952—54 dell'Istituto Tallassografico «F. Vercelli» di Trieste. pp. 76, 170.
17. Sezione mareografica del Centro di studi tallassografici del C. N. R. presso l'Istituto Tallassografico «F. Vercelli» di Trieste 1951—54. pp. 76, 173.
18. Establishment of an Inter-American oceanographic institute. pp. 64, 176.
19. Natural delimitation between the Pacific Ocean and the South Atlantic Ocean following the Arc of the Southern Antilles. pp. 63, 79, 178.
20. Physical Oceanography in Japan. See p. 29.

F. Symposium on Storm Surges.

1. Doodson, A. T.: Storm surges. pp. 36, 180.
2. Groen, P.: On the dynamics of wind surges in a bay or marginal sea. pp. 36, 184.
3. Rossiter, J. R.: The prediction of storm surges from meteorological forecasts. pp. 36, 187.
4. Proudman, J.: The dynamics of storm surges. pp. 44, 189.
5. Hellström, W.: Certain recent investigations in connection with storm surges. pp. 36. 191.
6. Hansen, W.: Dynamical investigations of storm surges. pp. 44, 193.
7. Goldsbrough, G. R.: Wind-effects on the motion of the sea in an infinite channel and in a rectangular gulf. pp. 44, 195.
8. Charnock, H.: The drag of the wind on the sea. pp. 50, 196.
9. Carruthers, J. N and Lawford, A. L.: The progress of the storm surge of January 31st/February 1st, 1953 indicated by current meter observations in the southern North Sea. pp. 41, 197.
10. Bowden, K. F.: The effect of flow through the Strait of Dover on storm surges in the North Sea. pp. 41, 199.

11. Egedal, J.: Some remarks on storm surges in interior Danish waters. pp. 41, 200.
12. Farquharson, W. I.: Probabilities of very high levels at certain ports on east coast of England. pp. 41, 202.
13. Munk, W. H : A numerical filter to reduce diurnal and semi-diurnal tides pp. 50, 203.
14. Hachey, H. B.: Storm surges and internal adjustments in the water mass. pp. 50, 204.
15. Freeman, J. C. and Bates, C. C.: Present status of storm surge research in the United States of America. pp. 50, 205.
16. Freeman, J. C., Jr.: Two-dimensional storm tides in shallow water. pp. 44, 206.
17. Schönfeld, J. C.: Combination effects of meteorological and astronomical tides. pp. 44, 209.

G. Symposium on Principles of Measuring Currents.

1. Böhnecke, G.: Principles of measuring currents. pp. 54, 210.
2. Carruthers, J. N.: New approaches in current-measuring. pp. 54, 212.
3. Joseph, J.: The paddle-wheel current meter and the bifilar current meter of the German Hydrographic Institute. pp. 54, 214.
4. Vaux, D.: The use of towed electrodes in shallow water. pp. 54, 216.
5. Mosby, H.: Propeller and pendulum for current measurements. pp. 54, 218.
6. Longuet-Higgins, M. S.: Principles of the method of towed electrodes. pp. 54, 219.
7. Von Arx, W. S.: Observational aspects of current measurements by the electromagnetic method. pp. 54, 221.

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2. Cahierre, L.: Relevés de la densité de l'eau de mer à la station marémétrique de Marseille. pp. 35, 225.
3. Doodson, A. T.: Film on ocean tides. pp. 35, 227.

4. HORN, W.: The translation into harmonic form of Lubbock's method for the prediction of high and low waters, and the application to analysis and prediction of punched-card machines. pp. 35, 228.

4.1. MERCANTON, P. L.: Les marées du lac Léman. pp. 35, 229.

4.2. LEGRAND, J.: Sur la recherche dans les archives anciennes de données sur les anciens niveaux des mers. pp. 69, 231.

Waves.

5. BERNARD, P.: Opportunité d'enregistrements de longue durée des ondes internes. pp. 62, 232.

6. BURLING, R. W.: The statistical distribution of wave heights. pp. 58, 234.

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7. LONGUET-HIGGINS, M. S.: Direction finding in sea waves. pp. 58, 237.

8. MIYOSHI, H. and AKIBA, Y.: The tsunamis caused by the Myojin explosions. pp. 61, 238.

9. MIYOSHI, H.: Generation of the tsunami in the compressible water. pp. 61, 239.

10. MUNK, W.: High frequency ocean waves. pp. 58, 240.

11. NAKANO, M., UNOKI, S. and KUGA, Y.: On the result of wave observations at Jogashima Island and its application to wave forecasting. pp. 58, 241.

12. TERADA, K., YASUI, Z. and ISHIGURO, S.: On the secondary undulation of Bay of Nagasaki. pp. 61, 243.

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13.1. WIEGEL, R. L.: Laboratory studies of gravity waves generated by the movement of a submerged body. pp. 61, 246.

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14. BERNARD, F.: Action des vents sur le courant Atlantique en Méditerranée. Facteurs physico-chimiques de la fertilité marine (plancton) au large de l'Algérie. pp. 32, 249.

14.1. Eggvin, J.: Current conditions in the Norwegian Sea based on recent material. pp. 65, 252.
15. Hidaka, K.: Zonal currents driven by winds. pp. 68, 253.
16. La Fond, E. C.: On the circulation of the surface layers off the east coast of India. pp. 67, 254.
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19. Tait, J. B.: Variations in the strength of the Atlantic Current in the Faroe-Shetland Channel. pp. 65, 258.

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20. Abe, T.: A study of the foaming of sea water. pp. 69, 260.
22. Bourcart, J.: Sur les possibilités de migrations de l'oxygène dans les profondeurs. pp. 33, 262.
23. Cooper, L. H. N.: Deep sea oceanography and biological productivity of shallow-seas. pp. 32, 263.
24. Day, A. A.: The physical character of some deep sea oozes. pp. 72, 264.
24.1. Emery, K. O.: Nutrient budget in the ocean. pp. 72, 265.
24.2. Fage, L.: Teneur en 0_2 de l'eau au voisinage du fond. pp. 76, 266.
25. Hidaka, K.: Areas of divergence and convergence of wind stresses in the Pacific as the possible indicators of upwelling and sinking. pp. 68, 268.
26. Hill, M. N.: The Topography of the mid-Atlantic Ridge. pp. 74, 269.
28. Jerlov, N.: The use of the Tyndall effect for studying particulate matter in the sea. pp. 69, 270.
28.1. Joseph, J.: The transport of suspended matter by tidal streams. pp. 69, 271.
29. Kullenberg, B.: The salinity of the interstitial water in recent sediments. pp. 74, 272.
30. Laurent, J.: Sur quelques phenomènes particuliers observés au cours des campagnes d'océanographie et d'hydrographie littorales. pp. 74, 274.
31. Le Floch, J.: Recherches océanographiques au large des côtes de Guyane et des bouches de l'Amazone. pp. 68, 278.
32. Le Grand, Y.: La pénétration de l'ultra-violet dans la mer. pp. 71, 280.

33. LUMBY, J. R.: The depth of the wind-produced homogeneous layer in the oceans. pp. 68, 282.
34. LUMBY, J. R. and FOLKARD, A.: Variations in the surface tension of sea water *in situ* pp. 71, 284.
35. MENACHÉ, M.: Simplification de la Table de titration de Martin Knudsen pour la détermination de la chlorinité de l'eau de mer. pp. 72, 286.
36.1. PICOTTI, M.: Unità di misura nelle ricerche chimico-fisiche-tallassografiche. pp. 76, 288.
37. POSTMA, H.: Transport of suspended matter in estuaries. pp. 74.
37.1. RAO, R. P.: Annual cycles of beach erosion at Waltair on Bay of Bengal. pp. 70, 290.
37.2. RAO, M. P. and MAHADEVAN, C.: The concretions near continental shelf off Visakhapatnam area. pp. 70, 292.
37.3. SHALEM, N.: Le plateau continental est Méditerranéen. pp. 76, 294.
38. UDA, M.: On the variation of water temperature due to the passage of typhoon. pp. 69, 297.
39. WISEMAN, J. D. H. and SMALES, A. A.: Significance of nickel and cobalt contents of deep-sea deposits and of sea-water. pp. 74, 299.

E 20. Printed copies were available of the Japanese National Report by KOJI HIDAKA: «Physical Oceanography in Japan in the Period 1951—52» (30 pages). Science Council of Japan. Ueno Park, Taito-Ku. Tokyo 1954.

EXCURSIONS

were arranged 19th, 24th and 26th September.

REPORTS OF MEETINGS

FIRST GENERAL MEETING OF THE ASSOCIATION

Tuesday, 14th September 1954.

The Meeting opened at 14.40, when the Chair was taken by the President, Professor PROUDMAN. Forty-six delegates and guests were present.

C 1. The report of the Committee on Tides, printed on p. 92, was adopted. It was recommended that the printing expenses in connection with the Bibliography on Tides 1665—1939 be paid, if necessary, from the reserves of the Association. This recommendation was adopted.

D 1. It was agreed that the Committee on Tides should continue its work and prepare a Bibliography for the years subsequent to 1939. Professor PROUDMAN was elected Chairman after the late MR. MARMER, M. GOUGENHEIM was elected Secretary and MR. DISNEY, Professor HIDAKA and Dr. SCHIJF were elected members of the Committee.

C 2. The report of the Committe on Mean Sea-Level and its Variations, printed on p. 93, was adopted. It was agreed that the full report of the Committee should be printed as a Scientific Publication and that the expenses should be paid, if necessary, from the reserves of the Association.

D 2. It was agreed that the Committee should continue its work. DR. DOODSON was elected Secretary after the late DR. CORKAN, and the resignation of DR. EGEDAL as member of the Committee was accepted. It was agreed that DR. DOODSON, Professor GROEN and Dr. HANSEN should consider the question of publishing Storm Surges data and prepare a proposal.

C 3. Postponed.

C 4. The report of the Committee on Oceanographical Observations from Atlantic Weather Ships, printed on p. 98, was adopted. It was agreed that the full report of the Committee should be printed as a Scientific Publication and that the expenses should be paid, if necessary, from the reserves of the Association.

D 4. It was agreed that the Committee should continue its work. The resignation of Professor MOSBY as secretary was accepted, and Mr. SÆLEN was elected new secretary. Dr. RAE was elected member after the late Professor LE GALL, and Dr. GOUGENHEIM was elected member after the resignation of Dr. RUSSELL.

C 5. Postponed.

C 6. Postponed.

C 7. Professor MOSBY reported that a Provisional Committee on the Geophysical Year 1957—58 had been established by the Bureau of the Association, on request of the International Special Committee on the Geophysical Year (CSAGI) and the General Secretary of the Union. This Committee consisted of the President, the Secretary and the Deputy Secretary of the Association and of representatives of the countries from which proposals concerning the Geophysical Year had been received.

D 7. It was agreed that the Provisional Committee on the Geophysical Year 1957—58 should prepare a proposal as soon as possible.

C 10. Postponed.

The Meeting closed at 15.10.

SECOND GENERAL MEETING OF THE ASSOCIATION

Wednesday, 15th September 1954.

The Meeting opened at 11.00, when the Chair was taken by the President, Professor PROUDMAN. Forty-four delegates and guests were present.

D 7. Professor PROUDMAN reported that the Provisional Committee on the Geophysical Year 1957—58 had held a Meeting on Tuesday, 14th September at 15.30. It was agreed that the Committe should be established as a regular Scientific Committee, with Dr. DEACON as Secretary and the following members: The Secretary of the Association, Dr. BÖHNECKE, Professor DEFANT, Dr. GOUGENHEIM, Dr. LONGUET-HIGGINS, Mr. LYMAN and Professor MUNK.

H 14. Professor F. BERNARD read his papers: «Action des vents sur le courant atlantique en Méditerranée» and «Facteurs physico-chimques de la fertilité marine (plancton) au large de l'Algérie. (See p. 249).

H 23. Dr. COOPER read his paper: «Deep sea oceanography and biological productivity of shallow seas». (See p. 263).

Dr. TAIT expressed some doubt, on account of the great bulk of water concerned and the shallowness of the region of origin he cites for this water, of Dr. COOPER's thesis that the cold bottom water of the North-East Atlantic in about lat. 52°N comes mainly from over the Faroe-Iceland Ridge, with a small addition from the Faroe-Shetland Channel, through the very narrow channel between Faroe Bank and the Suderoe Shelf. Dr. TAIT asked if Dr. COOPER had considered whether the cold bottom water in the North-East Atlantic Ocean may not have originated in the Greenland-Iceland Region.

Dr. COOPER replied that this had been examined. He has found no evidence that water as saline as 35.00 $^{0}/_{00}$ is sinking in the Greenland—Iceland Region, that there appears to be no salinity inversion at depth in the Labrador Basin and that the large body of water in the Eastern Basin which has those properties is completely separated from the Labrador or Western Basin by the Reykjanes Ridge. Furthermore to keep the pattern of densities consistent, much water would need to flow uphill. He agrees that he has not found evidence for a large volume of this water *in situ* over the Iceland—Faroe Ridge. This is, he believes, because, due to stress of weather, so few observations are available at the right time of year, March.

H 22. Professor BOURCART read his paper: «Sur les possibilités de migrations de l'oxygène dans les profondeurs». (See p. 262).

Dr. BERNARD: L'observation de M. BOURCART coincide avec nos constations en Algérie. Sur 56 minima de phytoplancton, 54 correspondent remarquablement avec la richesse de l'eau de mer, jusqu' à 25 milles des côtes, en grains de sable d'origine fluviatile (5 à 1.000 grains par ml.) — Ce sont donc les sables fins portés par les crues de rivières qui nuisent au plancton, bien qu'ils portent souvent des bulles d'air.

The Meeting closed at 12.15.

THIRD GENERAL MEETING OF THE ASSOCIATION

Wednesday, 15th September 1954.

The Meeting opened at 14.10, when the Chair was taken by the President, Professor PROUDMAN. Seventy-seven delegates and guests were present at the presidential address, about forty at the rest of the meeting.

The President addressed the audience as follows:

«I should like to welcome delegates and guests to the General Assembly of the International Association of Physical Oceanography, and to express the hope that our deliberation will be of much benefit to the subject.

Since the Assembly in Brussels in 1951, physical oceanography has suffered very seriously in the deaths of:

R. H. CORKAN, Great Britain.
V. W. EKMAN, Sweden.
C. FRANCIS-BOEUF, France.
J. le GALL, France.
R. JURVA, Finland.
R. LEGENDRE, France.
H. A. MARMER, United States.
OLAV MOSBY, Norway.
H. R. SEIWELL, United States.
T. WAYLAND VAUGHAN, United States.
F. VERCELLI, Italy.

These men had made notable contributions to the subject, and we honour their memory».

A. The President then gave his address on «The unkown tides of the oceans». (See p. 83).

H 3. Dr. DOODSON showed his «Film on ocean tides» (see p. 227).

H 4. Dr. HORN'S paper: «The translation into harmonic form of Lubbock's method for the prediction of high and low waters, and the application to analysis and prediction of punched-card machines» was read by title (see p. 228).

H 1. Dr. BOWDEN read his paper: «The effect of wind on tidal currents» (see p. 223).

H 2. Mr. CAHIERRE read his paper: «Relevés de la densité de l'eau de mer a la station marémétrique de Marseille» (see p. 225).

H4.1. Professor MERCANTON'S paper: «Les marées du lac Léman» was read by title (see p. 229).

Mr. MICHEL NAHAS' book: «La mécanique du globe et sa structure, Tome I, La mécanique extérieure, La théorie des marées» was presented. Copies of the book were at disposal for those interested.

C 7. Dr. DEACON reported on the meeting at 12.30 of the Committee on the Geophysical Year 1957—58. Report and recommendations were adopted (see p. 102).

The Meeting closed at 16.45.

FOURTH GENERAL MEETING OF THE ASSOCIATION

Thursday, 16th September 1954.

SYMPOSIUM ON STORM SURGES

The Meeting opened at 9.10, when the Chair was taken by the President, Professor PROUDMAN. Seventy-eight delegates and guests from the Associations of Physical Oceanography and of Meteorology were present.

F 1. Dr. DOODSON read his paper: «Storm surges» (see p. 180).
F 2. Professor GROEN read his paper: «On the dynamics of wind surges in a bay or marginal sea» (see p. 184).
F 5. Professor HELLSTRÖM read his paper: «Certain recent investigations in connection with storm surges» (see p. 191).
F 3. Mr. ROSSITER read his paper: «The prediction of storm surges from meteorological forecasts» (see p. 187).

Discussion started at 11.10.

Dr. FREEMAN: Dr. GROEN, what value do you take for the bottom friction when the net transport is zero?

Professor GROEN: In case of zero net transport there is indeed a bottom current that gives rise to a small bottom friction. The bottom stress will in that case probably be less than one fifth to one tenth of the wind stress. It works, in general, in the same direction as the wind stress and may be combined with it to form a sort of «effective wind stress».

Professor HELLSTRÖM: For the bottom the equivalent sand roughness was taken at $k_s = 2$ cm. The length of turbulence at the water surface has been taken at $m = 0.2$ cm.

Professor MUNK: Van Dorn has attempted to measure the bottom stress by means of a disk flush with the bottom, somewhat

similar to the arrangement used by Sheppard to measure wind stress. He was not able to detect a bottom stress in a basin 200 m. long and 10 feet deep. This places the bottom stress at perhaps less than 10 per cent of the surface stress.

Mr. URSELL: The equilibrium slope due to a wind stress has been studied by G. KEULEGAN (J. Res. Nat. Bu. Stand. Wash., 1951) when the total mass transport in the water is zero. For laminar flow he finds that the bottom stress is about one-half the surface stress. An equivalent statement is that the bottom stress may be ignored provided that the actual depth is replaced by an equivalent depth (about 2/3 the actual depth) at which the backflow is a maximum. In turbulent flow an experiment by FRANCIS (J. Mar. Res., 1953) shows that the equivalent depth may be about 4/5 the actual depth. This analysis is valid only when a steady state has been attained and when the effect of end walls is negligible.

Dr. SCHIJF: As regards the bottom friction in the case of unidirectional equilibrium set up, a theoretical evaluation may be tried based upon conceptions of distribution of turbulence according to Prandtl and von Kármán. With certain reasonable assumptions this leads to a ratio between bottom (friction) stress and surface (wind) stress of rather less than 10 per cent.

Capt. HUNT: In considering the relation between the value of the surface shear stress and the bottom shear stress the two factors of primary importance seem to be the depth of water D, and the relative roughness of the bottom, k. Simplifying the equations of motion one gets

$$\frac{\partial h}{\partial x} = \frac{\partial}{\partial z}\left(\varepsilon \frac{\partial u}{\partial z}\right)$$

By making assumptions as to the distribution of the coefficient of eddy viscosity (ε) the relation between the stress at the surface and bottom may be determined. It appears as if $\frac{\tau_{bottom}}{\tau_{surface}} = 0.10$ or less, depending as the value of $\frac{D}{k}$.

Mr. WIEGEL: 1) The bottom roughness affects the height of the run-up due to wind stress by a considerable amount (Laboratory observation). 2) Experiments with dye in the water show that

considerable macroscopic turbulence exists in a closed basin when wind blows over the water surface.

Professor PROUDMAN: How did Dr. GROEN calculate the curvature in his lines of equal disturbance of level?

Professor GROEN: The «iso-disturbance lines» that were shown are based on shore data *and* on a certain amount of physical reasoning and of imagination.

Dr. SUTCLIFFE: To what extent are the verifications of prediction formulae due to lack of sufficiently accurate and representative meteorological data?

Professor GROEN: At present the meteorological information from the greater part of the North Sea is too poor for any very exact application of storm surge forecasting methods.

Professor HELLSTRÖM: It would be desirable to get from the meteorologists also information regarding the direction as well as the velocity of the wind.

Dr. SUTCLIFFE: Pressure gradient is a more representative parameter than wind and may be better to use than surface winds.

Capt. HUNT: It has been determined from an exceedingly large amount of data at Lake Okeechobee, Florida, that there is a reduction in the wind speed at a given height over water as the wind approaches a shoreline. The reduction factor was constantly 0.89.

As has been presented the shear stress varies as the square of the wind velocity. Thus it is important to consider where the wind velocity measurements are made (on shore, over water etc.)or fairly large errors may result.

Dr. DOODSON: We realize that meteorological forecasts cannot be perfect, but a calculation should be carried out to indicate the probable size of the surge. But in the North Sea a watch upon the progress of the surge is a necessary and desirable system so that the calculations can be revised as the surge progresses.

Professor SVERDRUP: Knowledge of the distribution of atmospheric pressure and its variation can never be a wholly satisfactory substitute for direct wind observations because owing to accelerations the wind may deviate considerably from the geostrophic or gradient wind.

Mr. NEUMANN: I believe that not only the use of wind observations but also those of atmospheric pressure differences requires some caution. In bad weather, fluctuations of pressure are not

negligible. Because of these fluctuations, pressure differences between two stations, based on instantaneous readings of barometers, might differ sensibly from the average of readings taken over, say, ten minutes.

Dr. STAGG: Does all this mean that we must envisage a network of observing stations in the North Sea before reliable forecasts of surges can be made?

Professor GROEN: As a matter of fact, thought is already being given to the idea of having one regular meteorogical station in the middle North Sea, either as an anchored weather ship, or even as a rigid structure, to be built on the Dogger Bank.

Mr. ROSSITER: I should like to support the remarks made by Dr. GROEN and Dr. HELLSTRÖM and the almost unavoidable inadequacy of the meteorological data available for storm surge research. Recent work on surges at Liverpool shows the increased accuracy of predictions when actually observed velocities and directions from the Isle of Man (a fixed weather station in the centre of the Sea) and Bidston (open to the full force of the sea winds) are used as opposed to isobar gradients. I may add the rather obvious remark that isobars give better results when the pressure field is uniform than when the isobars have a radius of curvature, as when a depression passes over the sea.

Professor HELLSTRÖM: I want to support what Dr. ROSSITER has just said. I also want to stress the importance of the paper on meteorological effect published by Proudman and Doodson in 1924.

Dr. PENMAN: Would it not be worth while concentrating effort on devising equipment to measure surface shear direct? This would obviate the need for a complex set of wind data that have to be fitted into an uncertain equation.

Professor PROUDMAN: Can the coding for an electronic calculating machine be done sufficiently rapidly for forecasting storm-surges?

Dr. SUTCLIFFE: If the calculations can be programmed for electronic computing they could almost certainly be carried out very quickly on a routine forecasting basis. Time required to introduce the actual data for the occasion would be quite small.

Dr. CARRUTHERS drew attention to the existence in the critical area of the southern North Sea of a virtual network of Weather

Ships in the form of the numerous lightships present here. — As regards imperfections of pressure inferred winds, due regard is paid to refractions in direction and reduction in speed by the German (Dietrich) wind service based upon pressure triangles good for three divisions of the North Sea. — Rarely do pressure-inferred winds differ from actual lightship observations when whole-day (and longer) averages are in question.

Dr. MORTIMER: The examples of practical importance, of which we have heard today, are essentially non-stratified. In stratified systems (*e. g.* lakes in summer) «bottom friction» is largely transformed into a very low thermocline friction, and a part of the wind stress produces a slope of the thermocline. The free period of this boundary is, of course, very much longer than that of the water surface. It would be of great interest to know whether Proudman and Doodson's theory of the response of the water to meteorological effects could be extended to stratified cases.

Professor PROUDMAN: The theory can be extended to the case of stratified water.

Professor HELLSTRÖM: In 1941 I published a paper dealing with stratified water under steady conditions. The North Sea may be considered as having homogeneous water as an approximation. In the Baltic, however, there is a thermocline in summer but not in autumn.

The Meeting closed at 11.40

FIFTH GENERAL MEETING OF THE ASSOCIATION

Thursday, 16th September 1954.

SYMPOSIUM ON STORM SURGES

The Meeting opened at 14.05, when at the request of the President, the Chair was taken by Professor SVERDRUP. Sixty-one delegates and guests from the Associations of Physical Oceanography and of Meteorology were present.

F 9. Dr. CARRUTHERS read the paper by CARRUTHERS and LAWFORD: «The progress of the storm surge of January 31st/February 1st, 1953 as indicated by current meter observations in the southern North Sea» (see p. 197).

F 10. Mr. BOWDEN read his paper: «The effect of flow through the Strait of Dover on storm surges in the North Sea» (see p. 199).

F 11. Dr. EGEDAL was not present; Dr. DOODSON made some remarks concerning Dr. EGEDAL's paper: «Some remarks on storm-surges in interior Danish waters» (see p. 200).

F 12. Dr. FARQUHARSON read his paper: »Probabilities of very high levels at certain ports on east coast of England» (see p. 202), and at the request of Dr. DOODSON reported briefly on certain sea-level investigations.

Discussion from 14.50 to 15.25.

Dr. DOODSON: I support what has been said regarding the value of observations of currents. These observations cannot be used in forecasting but they will help in the understanding of what takes place. Also they will enable the lines of equal height of storm surge in the open sea to be drawn with grater accuracy.

Dr. LONGUET-HIGGINS: Recent obeservations by Mr. Henry Stommel who has used telegraph cables from Bermuda and the

Azores, may provide information as to tidal stream velocities in the North Atlantic.

Professor MUNK: Dr. Cooper's remarks about a low Atlantic sea-level in northern spring must be interpreted in terms of the fact that a similar condition is found in the North Pacific, and that the southern Oceans are low in southern spring.

Professor THIJSSE: Observations on the coast of Holland agree with those mentioned by Commander Farquharson. Also the mean value is of the same order of magnitude. Tilting of the country shows that the land is moving as well as the sea-level. — Are the tide gauges quite stable? Local settling often complicates matters in Holland.

Dr. DOODSON: The matter of changes in mean sea-level is important with regard to the matter of probability of recurrence. Engineers need the assistance of scientists engaged on storm surge research; they need to have some measure of probability. In making such estimates, however, it is necessary to examine whether mean sea-level is changing or not.

Mr. BOWDEN: 1) I agree with the shape of the velocity profile for gradient flow drawn by Dr. Hellström. 2) In applying the empirical equation $V = aW^2 \cos \Phi + b\Delta Z$, a steady state is assumed so that $\frac{\partial V}{\partial t} = 0$. The term $V \frac{\partial V}{\partial x}$ is also neglected, as being small compared with the others. The fact that V is put proportional to ΔZ instead of $\sqrt{\Delta Z}$ depends on the assumption that the drift current is superimposed on a tidal current of greater amplitude.

Dr. CARRUTHERS: As regards this point about the efficacy of wind to add water depth being dependent upon existing depth, we have been finding that wind effects in urging water into the Southern North Sea do markedly depend upon whether the situation is Neaps or Springs. At Springs there seems to be a greater hydraulic resistance against further deepening — and the currents swerve more and more against the clock.

Dr. SCHIJF: Investigations in this subject in Holland seem to indicate that there is a tendency for high setups to coincide rather with high than with low tides. However, from a research into the mechanics of the interplay of tide and windstress it emerges that

more factors enter into the problem than simply the influence of a greater or lesser depth. The fact if the wind is with or against the tidal current has a decided bearing on the resulting motion, because of the quadratic character of the bottom friction.

Professor GROEN: To what Mr. Schijf has said I should like to add that besides the interaction of the tidal current with the drift current, the alternating tidal current has a marked effect on the *relative wind* speed (with regard to the water), which determines the wind stress, so that even if the wind were steady the tidal current would cause an oscillating wind stress.

Mr. von ARX showed a Film on storm surges.

The Meeting closed at 15.40.

SIXTH GENERAL MEETING OF THE ASSOCIATION

Friday, 17th September 1954.

STORM SURGES

The Meeting opened at 9.00, when the Chair was taken by the President, Professor PROUDMAN. Forty-one delegates and guests were present.

The President appointed a committee to prepare nominations for the elections. This committee consisted of Dr. DEACON, Dr. GOUGENHEIM, Professor MUNK, and Mr. THOMSEN.

F 6. Dr. HANSEN read his paper: «Dynamical investigations of storm surges» (see p. 193).

F 7. Professor GOLDSBROUGH read his paper: «Wind-effects on the motion of the sea in an infinite channel and in a rectangular gulf» (see p. 195).

F 4. Professor PROUDMAN read his paper: «The dynamics of storm surges» (see p. 189).

F 17. Dr. SCHÖNFELD'S paper: «Combination effects of meteorological and astronomical tides», was read by title (see p. 202).

F 16. Dr. FREEMAN read his paper: «Two-dimensional storm tides in shallow water» (see p. 206).

Discussion started at 10.45.

Professor GROEN: In connection with Dr. Hansen's computation of the surge heights in the North Sea for the 31 Jan. 1953 storm, I should like to ask whether he has taken into account (1) the strong inhomogeneity of the wind field, which caused strong currents in the North Sea, and (2) the escape of water through the Straits of Dover. These two facts must have had pronounced effects on the disturbance heights in the southern North Sea.

Dr. HANSEN: Für das hier mitgeteilte Verfahren zur Ermittlung der zeitabhängigen Gestalt der Meeresoberfläche ist ein örtlich konstanter aber zeitlich sinusförmig veränderlicher Wind benutzt worden, da die für die Sturmflut vom Januar 1953 gültigen Windverteilungen noch nicht zur Verfügung standen. Das Verfahren gestaltet aber ohne Schwierigkeiten jede örtliche und zeitliche Änderung des Windfeldes ebenso wie die natürliche Gestalt der Nordsee zu berücksichtigen.

Dr. SCHIJF: I believe the method as set forth by Dr. Freeman will be very valuable for the discussion of storm surges. In Holland research along similar lines are going on. However, I have been surprised at his opening remarks. A method of this type, known as the method of characteristics, has been in use for some time for channel flow. It dates back to the Belgian *Massan* who published it around 1900

Dr. FREEMAN: My introduction was meant to convey that the method of characteristics is an old method and I certainly should have mentioned the work of *Massan*.

Professor PROUDMAN: Dr. Freeman, is it possible by this method to compute the transport of water?

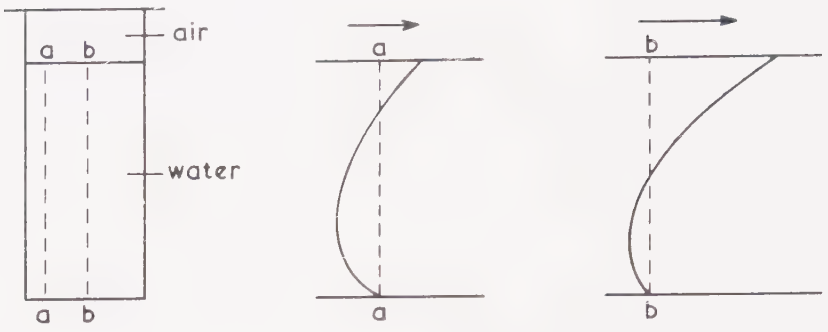
Dr. FREEMAN: Yes, the method will compute the transports.

Professor GOLDSBROUGH: 1) Does the formula used in the last slide refer to the motion on the centre line only? 2) What sort of values of the constant R would be appropriate in numerical work?

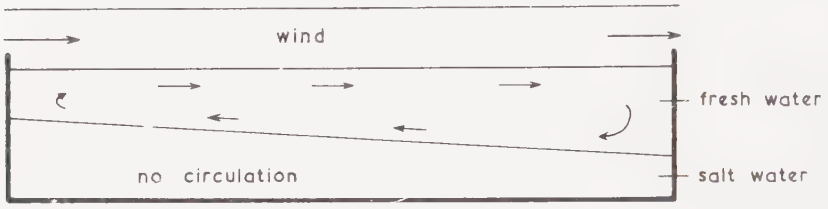
Professor THIJSSE: When predicting the effect of enclosing the Zuidersee, Lorentz developed a method for calculating tides. He too linearised the friction term. The condition for this term was that the work, done by the linearised friction (during one tidal period) should be equal to the work done by the exact (quadratic) friction. In this way no deformation of the waves can be calculated, but speed of propagation (slightly less than $\sqrt{gh}$) and damping are quite right.

Such techniques have been applied to the motions of fluids of uniform density. The two layer case has special complexities when the model is in rotation due to 2 seats of vertical stretching and shrinking and associated vorticity changes which differ in the two layers so that the natural case can only be approximated.

Professor HELLSTRÖM:



a—a distribution of velocity near the wall of a narrow test channel, b—b distribution in the middle



Wind stress on the surface may be measured be using stratified water as shown in the diagram.

Dr. CARRUTHERS: Would it not by very useful to go straight to Nature and observe the actual velocity profiles instrumentally in the North Sea itself? It can be done and would give escape from the great difficulties of transferring information got from models to natural situations.

Professor MUNK: Dr. Francis in England has found a very nice method of introducing «stress» to the surface by horizontally injecting known amounts of water through bent glass tubes with openings just beneath the surface, and draining corresponding amounts elsewhere.

Dr. DOODSON: It is necessary to utter a few words of caution with regard to the use of models because of the changes in dimensions. In tide models it is necessary to use artificial friction. It is sometimes said that the results of any tidal model need to be inter-

preted by a competent engineer, but there might be differences of view with regard to the interpretation. The subject is very complex, and great caution is needed.

Dr. DEACON suggested that type problems such as those discussed by Professor Goldsbrough and Professor Proudman might be advanced by experiments in models. One of Professor Goldsbrough's conclusions was that with a certain depth of water the surface would slope downwards in the direction of the wind. No one had observed such a thing, but the assumptions on which the conclusion was based are reasonable, and it might be observed if a sufficient range of conditions could be covered in nature or produced artificially in a model. It was becoming practicable to make rotating models, but the laboratories who had such facilities had been more or less compelled to make them look like the final problem with all its complexities and had in consequence added little to our knowledge of the basic principles. It seemed likely that the mathematicians might use *simple* models to get over some of the theoretical difficulties.

Professor THIJSSE: It is feasible to make a rotating model of the North Sea. In Holland there is a project for such a model; the diameter will be 50 feet or slightly more. I am confident that such a model will give the correct tides. The difficulty is the reproduction of the shear by the wind, but I trust this will be solved.

Dr. SCHIJF: Next to a hydraulic model it could be considered to treat storm surge problems in an electric analogy model. In principle the design of such a model is perfectly feasible.

Dr. DEACON said that he thought that we really had to decide whether we should obtain results more quickly by using models of actual seas, or by simple models, straight channels for example, to attack one question at a time.

Mr. von ARX: I quite agree with Dr. Deacon's suggestion that many of the complexities of the storm surge problem may be resolved by means of rotating hydraulic models by simple rectangular channels and bays. A rotating platform 5 meters in diameter is under construction at Woods Hole which will be used for these purposes and for the study of the wind driven ocean circulations of the whole Northern and Southern hemispheres.

Professor THIJSSE: I agree with Dr. Doodson that a model should be made and operated by competent people; sometimes

this is not the case and then the results are such that they undermine the confidence in models. The bottom friction has to be carefully looked into. Artificial roughness has to be applied. No model should be used for making predictions unless it has first proved that it correctly reproduces existing conditions (passed its examination). A model (at Delft) of the southwestern estuaries in Holland has passed its examination and is now being used for predicting the consequences of damming those estuaries one after the other.

Mr. BOWDEN: I should like to ask about the value of eddy viscosity which should be taken. What assumption did Dr. Hansen make about the eddy viscosity in his calculations and is it possible to learn anything about its numerical value from the comparison of observations with calculations?

Mr. HANSEN: Die Reibung wird etwa in der Weise berücksichtigt dass in den hydrodynamischen Differentialgleichungen alle Funktionen nach der Tiefe entwickelt werden unter Benutzung der Bedingungen an der freien Oberfläche.

Dr. DOODSON: I have some difficulty in understanding Mr. Freeman's use of T_x and T_y in forecasts, as these depend upon velocities of currents out at sea. How are these known during the progress of a surge in the vicinity?

Dr. FREEMAN: The transports must be computed from values that were known before the storm.

Professor FJELDSTAD to Dr. FREEMAN: I can imagine that the surface elevations may be computed, but not surface velocities, unless you make some assumption regarding the velocity profile, when your equations only contain mass transport.

Dr. DOODSON: May I ask whether progress has been made in the electrical model with regard to the rotational effects?

Dr. SCHIJF: In an electric analogy model the wind stress would have to be introduced as an additional potential. The matter does not seem to present undue difficulties but it has not yet been studied in detail.

The object of the investigation will have to be divided gridwise into sections with suitable connections both lengthwise and crosswise. The Coriolis effect can be introduced by an additional system of connections, providing a potential controlled by the flow at right angles.

Professor GROEN: As to the technique of electrical models I

might remark that, for the steady state solution of the differential equations, it is the stream function field of the mass transport that is found first, as a potential field. The vorticity of the wind stress field is applied as an input of electrical current at grid points of the model, the boundaries of the model being kept at a constant potential.

The Meeting closed at 11.30.

SEVENTH GENERAL MEETING OF THE ASSOCIATION

Friday, 17th September 1954.

STORM SURGES

The Meeting opened at 14.05, when at the request of the President, the Chair was taken by Dr. CARRUTHERS. Fifty-seven delegates and guests were present.

The President announced that the book by the late Dr. R. H. CORKAN: «Storm Surges in the North Sea», Vol. I and Vol. II, 1948, which is hardly available, might be inspected in the Secretariat.

F 8. Mr. CHARNOCK read his paper: «The drag of the wind on the sea» (see p. 196).

F 13. Professor MUNK read his paper: «A numerical filter to reduce diurnal and semidiurnal tides» (see p. 203).

F 14. Dr. HACHEY read his paper: «Storm surges and internal adjustments in the water mass» (see p. 204).

F 15. Dr. FREEMAN read the paper by FREEMAN and BATES: «Present status of storm surge research in the United States of America» (see p. 205).

Discussion started at 15.35.

On Mr. CHARNOCK'S paper F 8.

Professor FJELDSTAD: For wind profiles I have a formula which has not yet been published: $\tau_o^2 = 2(l\varsigma)^2 \int_0^H R^2 z dz$

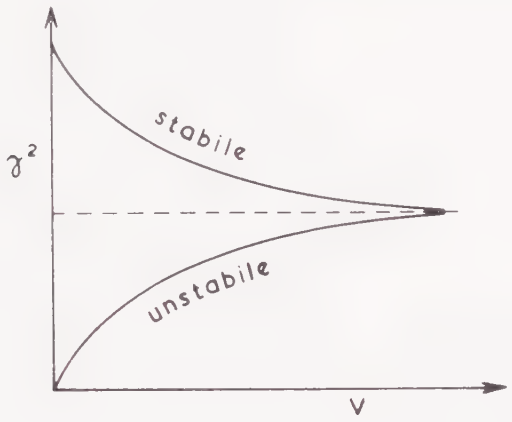
where $R^2 = (U-u)^2 + v^2$

(U gradient velocity). This formula applied to the «Leipzig Windprofile» treated by *H. Lettau,* gives for τ_0 the value 5.33

dyns/cm^2 which is also the value found by *Lettau* by another formula. If we represent this value of the stress by $\tau = \varsigma k^2 V^2$, we should have to introduce the velocity in 150 m height with the conventional value of k^2. This relates to wind over land and the stress over a sea surface is probably less.

Mr. CHARNOCK: I have no experience of Dr. Fjeldstad's formula — the drag is greater over land than over the sea.

Capt. HUNT: Investigations of wind profile and temperature gradients at Lake Hefner have shown that the air-water temperature stability is very important. If $\tau = \gamma^2 \varsigma a V^2$, we have



Investigations have shown that there is an increase in the drag for the same wind speed and stability conditions when waves are present over when they are not.

Mr. CHARNOCK: The effect of stability is probably to increase the drag at a given windspeed. No satisfying evidence for a discontinuity has been published.

Mr. von ARX: It is comforting to learn from Mr. Charnock that he had to consider the downward flux of momentum from altitudes very much higher than those ordinarily assigned to the top of the «layer of frictional influence» above which the winds are approximately geostrophic. *Starr* and *White*, among others, have found that the level in the atmosphere at which the poleward flux of angular momentum is maximum is that of the jet stream, and that important contributions occur at levels as low as 500 millibars. Thus while the mechanism of the vertical flux of momentum

remains obscure it seems clear from Dr. Charnock's findings that the vertical transfer of angular momentum involves a thicker layer of the lower atmosphere than that in which the winds are usually ageostrophic.

Dr. DOODSON: I think it necessary to call attention to the values of n and k in the formula for the wind stress, and I judge that the evidence is strongly in favour of taking $n = 2$, $k = 0.0025$ and that if any observations indicate values differing from these, the explanation must be sought in the physical circumstances. I have examined data for which $n = 1.8$ has been used and find that statistical methods indicate no justification for departure from $n = 2$.

Mr. CHARNOCK: There is a large amount of data, of variable quality. Statistical analyses of different parts of these data give conflicting results. In particular, data derived from tilt measurements give greater values than do other methods.

Professor HELLSTRÖM: Some time before I left Stockholm for this meeting I made an analysis of the coefficient n. The result of my work was very much in agreement with the views expressed by Dr. Doodson.

Professor THIJSSE: Values of k on Yssel Lake have an average of 0.0025 too. It may be higher (young short waves, travelling slowly) or lower (opposite conditions). In a wind-flume in the laboratory the same average value is found; it varies strongly. If oil is poured on the water k is less than 0.001.

On Professor MUNK's paper F 13.

Dr. DOODSON: I am not any more able than Dr. Munk to explain continued oscillations of period about 4 days, and extending over 3 months. The only other instance I can remember is from the Ross Sea. *Darwin* analysed the «Discovery» observations and noted a persistent oscillation of period about 3 days. As for fortnightly observations there is a very small tide Mf indicated by the potential, but generally speaking fortnightly tides obtained in tidal analyses are due to a shallow water tide due to the interaction of semidiurnal constituents. These are generated at the same time as quarter-diurnal constituents. Analyses over many years show sufficient agreement to justify their use in tidal prediction.

Mr. URSELL: In principle the method of convolution used by

Munk may be used whenever the different wave-components in a record are to be multiplied by different attenuation factors. Some years ago we designed an optical filter to deduce bottom pressure from surface elevation of ocean waves, but unfortunately this was never constructed. Dr. Munk is to be congratulated on his successful application of the mathematical concept.

On Dr. HACHEY's paper F 14.

Dr. DEACON asked Dr. Hachey if he had been able to form any estimate of the rate of travel of the water disturbances.

Commander LUMBY: Could Dr. Hachey say if he had any data which would allow an estimate to be made of the speed with which the water masses moved as the system changes during the passage of the storm?

Dr. HACHEY: From the time of formation of these cyclones, an interval of 8 to 10 days or more is usually involved before the storm centre reaches the Halifax-area. We have recorded these disturbances in the temperatures and salinities from four to eight days in advance of the arrival of the storm.

Dr. FREEMAN: Did you imply that the motion of the water into the bay gave an indication of the path of the storm?

Dr. HACHEY: We have no method of determining, from our observations in Halifax harbour, whether the storm centre will proceed on a normal path or whether it will move in on the coast.

The Meeting closed at 16.20.

EIGHTH GENERAL MEETING OF THE ASSOCIATION

Saturday, 18th September 1954.

SYMPOSIUM ON PRINCIPLES OF MEASURING CURRENTS

The Meeting opened at 9.10, when the Chair was taken by the President, Professor PROUDMAN. Forty-four delegates and guests were present.

G 1. Dr. BÖHNECKE read his paper: «Principles of measuring currents» (see p. 210).

G 2. Dr. CARRUTHERS read his paper: »New approaches in current-measuring» (see p. 212).

G 6. Dr. LONGUET-HIGGINS read his paper: «Principles of the method of towed electrodes» (see p. 219).

G 7. Mr. von ARX read his paper: «Observational aspects of current measurements by the electromagnetic method» (see p. 221).

G 4. Mr. VAUX read his paper: «The use of towed electrodes in shallow water» (see p. 216).

G 3. Dr. JOSEPH read his paper: «The paddle-wheel current meter and the bifilar current meter of the German Hydrographic Institute» (see p. 214).

G 5. Professor MOSBY read his paper: «Propeller and pendulum for current measurements» (see p. 218).

Dr. EGGVIN read a paper: «Current measurements in a modified Ekman meter way, the instrument suspended from the research ship» .

Professor FJELDSTAD briefly explained certain changes made in the construction of the Dahl-Fjeldstad current meter.

Discussion started at 12.50.

Professor MOSBY: 1) Would it be possible to apply the electrokinetic method on a telephone cable across a channel, less than 1000 m in width and with a maximum depth between 200 and 300 m? 2) Might it be possible by electrodes at both ends of the cable to record the water transport within different layers alternatively?

Dr. LONGUET-HIGGINS: In the example given by Professor Mosby the ratio of the width of the channel to its depth is about five to one. The ratio of the mean resistivity of the bottom to the resistivity of the water is probably much greater than this, and therefore there is probably little return flow of electricity through the bottom. In that case the voltage between the two sides of the channel, as measured by means of a stationary cable, should correspond to the mean velocity in a cross-section of the channel. It is equal to

$$V H_z L \times 10^{-8} \text{ volts}$$

where V is the velocity measured in cm/sec, H_z is the vertical component of magnetic field in Gauss, and L is the width of the channel in cm.

Mr. von ARX: The tidal signature (electrical) in a long narrow fjord, remote from other tidal channels should be a reliable index of the volume of flow on magnetically quiet days. In a tidal channel which is part of a complex network of tidal channels (such as that at Woods Hole, for example) the signals from nearby tidal channels will confuse the signals from the channel which the electrodes actually span.

Vertical arrays of fixed electrodes may be used as well as horizontal arrays to probe the vertical structure of flow. Only a little work has been done on these variations of the electromagnetic method of current measurement.

Mr. VAUX: Would someone (e. g. from National Institute of Oceanography) comment of the possibility of using stronger magnetic fields to reduce the scale of electro-magnetic equipment.

Mr. TUCKER: At the National Institute of Oceanography we have developed an electromagnetic flow meter which operates by producing its own strong magnetic field locally, and measuring the e.m.f. produced as the water current flows through this field.

The development follows other workers, notably *Guelke and Shoute-Vanneck* in South Africa. The measuring head is 10 cm in diameter and the field alternates at 50 c/s, in order to make amplification of the voltage easier.

The device is complicated electronically, but has the advantage of linear and very rapid response, so that it should prove useful for research purposes.

Mr. BOWDEN: The electromagnetic flow meter has been used to measure turbulence in the sea off Anglesey in North Wales. The horizontal and vertical components of flow at one unit can be recorded simultaneously. Alternatively, using two units, the horizontal or vertical components at the two units, with a given vertical separation, may be recorded. The records were obtained about six weeks ago and have not yet been analysed.

Dr. LONGUET-HIGGINS: Mr. Vaux found that the voltage by towed electrodes was about three-quarters of the induced electromotive force. This indicates that there must have been a large return flow of electric current through the sea bed. The observed voltage was therefore probably determined largely by the tidal streams in the North Sea to the east of the area of observation. In 1917, *Young, Gerrard, and Jevons*, made similar observations at the mouth of the river Dart and found that the observed voltage was in phase with the stream in the main part of the English Channel, not with the tide between the electrodes. (Phil. Mag. 1918, p. 149). The similarity of the voltage and the local streams in Mr. Vaux's observations shows only that the local streams are in phase with the general stream system in that part of the North Sea.

Young, Gerrard and *Jevons* were the first to use towed electrodes, and invented the «tidal square». Their observed electrical current-densities were sometimes in the same direction as the local stream and sometimes not. The discrepancies may be partly due to the non-uniformity of the streams in the English Channel, which must produce a component of electrical current-density along the channel.

Professor MOSBY: Would it be possible to eliminate the disturbing effect of the alternating currents within the bottom by simultaneous recording?

Mr. von ARX: Electromagnetic measurements of water currents in shallow water may be improved by permitting the electrode

string to come to rest on the bottom from time to time to measure $V' = (V \times H) - \varsigma i$.

Since underway the signal observed $V = -\varsigma i$ the sum $V' + V = \varepsilon = (V \times H)$, which one would like to measure.

The Meeting closed at 13.15.

NINTH GENERAL MEETING OF THE ASSOCIATION

Monday, 20th September 1954.

The Meeting opened at 9.05, when the Chair was taken by the President, Professor PROUDMAN. Forty-one delegates and guests were present.

H 6. Mr. BURLING read his paper: «The statistical distribution of wave heights» (see p. 234).

H 10. Professor MUNK read his paper: «High frequency ocean waves» (see p. 240).

H 13.2. Dr. VALEMBOIS read his paper: «Une méthode simplifiée pour l'étude de la propagation de la houle» (see p. 248).

H 7. Dr. LONGUET-HIGGINS read his paper: «Direction finding in sea waves» (see p. 237).

H 11. The paper by NAKANO, UNOKI and KUGA: «On the result of wave observations at Jogashima Island and its application to wave forecasting», was read by title (see p. 241).

H 13. Mr. TUCKER read his paper: »A shipborne wave recorder» (see p. 245).

H 6.1 The paper by CARTWRIGHT: «Directionality of waves measured by shipborne wave recorder» was read by Mr. TUCKER. (see p. 235).

H 6.2. Professor HELLSTRÖM read his paper: «Forces on a lighthouse located in 12 m depth».

Discussion started at 11.35.

Dr. WIEGEL: The fact that the slope distribution at short waves (ripples, etc.) was found to be Gaussian in all directions is, I believe, due to the basic reason for formation of waves. That is, the first ripples are formed by the variation of vertical pressure fluctuation (i. e. turbulence). These should have a Gaussian distribution in a

direction normal to the direction of wave travel as well as in the direction of wave travel. Some recent experiments by *Ralls* (University of California) in a windtunnel-ripple tank seem to verify this. It is premature to state the exact findings at this time as they are the subject of a thesis.

Professor MUNK: The distribution is roughly Gaussian for both the components along the mean wind and normal to it.

Mr. BOWDEN: I should like to ask a question arising from Dr. Munk's equation for the stress on the sea in terms of the wave spectrum. This takes into account the effects of normal pressures only. Can this be reconciled with earlier ideas on wind stress and wave generation that both normal pressures and tangential stresses, analogous to skin friction, are effective? The observations of *Keulegan* and *Van Dorn* might be interpreted as the effect of a detergent being to eliminate the normal pressures, leaving a reduced stress due to tangential forces only.

Professor MUNK: Yes, there are at least two fundamental processes whereby momentum is transported from the wind to the sea. One is by Tangential Stress, and is equal to the product (viscosity) $\times$ (vertical shear) evaluated *at* the surface; the other arises from systematic differences in pressure on the windward and the lea sides of obstacles. My remarks were referring only to the second process.

Dr. DEACON said that there was one difference between the observations of Munk and Neumann and those of Darbyshire which might prove to be significant. Those of Munk and Neumann were made in deep water and Darbyshire's in the coastal region. Now that Darbyshire had wave recordings from deep water he was finding that the same winds gave higher and shorter waves in deep water. No complete explanation is available but it may prove that the coastal region, which has tidal streams which must be very irregular, is not so favourable for the generation and propagation of waves. It seemed in particular that the growth of the short wave lengths was hindered. When Darbyshire produced an empirical equation for wave steepness in deep water it would probably not have $W^{\frac{1}{2}}$ in the denominator and we might have to face up to the fact that no simple equation, which did not take account of the disturbed nature of the water in currents and tidal streams, would give the wave spectrum in all parts of the oceans.

Mr. WIEGEL: Some experiments we are undertaking on the generation of waves by wind in a covered tank type wind tunnel show that for a given wind velocity and fetch the waves generated in shallow water are lower than those generated in deep water.

Mr. URSELL: Mr. Valembois has assumed that on each side of the vertical plane of transition the water motion can be expressed as the sum of simple sine waves; this allows the determination of two constants, and in most cases (e. g. the reflexion from a step in the bottom) the velocity is not continuous across the vertical plane of transition. In these cases an infinite number of standing waves (small except in the neighbourhood of the transition) should be added on each side, see *T. H. Havelock*, Phil. Mag. (7), 8, 1929, p. 569. The assumption of Mr. Valembois is, however, satisfied for the flow through a thin grid with a linear resistance law. I have investigated theoretically a thin grid in front of a vertical wall (perfect reflector), and have shown that at one frequence, depending on the resistance parameter, the absorption is complete, if the distance between wall and grid is a quarter-wavelength. Experiments to check this result are in progress. Mr. Valembois' assumption might be expected to increase in validity as the wavelength increases. His result for reflexion from a step, however, seems to be different from that of Lamb (Hydrodynamics, 6th ed., Cambridge 1932).

Professor MUNK: Barber's method of measuring wave direction as reported in NATURE several years ago may be mentioned here. It consists of using a reduced aerial photograph of the sea surface as a diffraction grating. The difficulty consists of interpreting the meaning of the varying brightness of the sea surface as it appears on the photograph (or as it is seen). It may now be possible, as pointed out by *Cox*, that an interpretation can be made from a knowledge of the distribution of slopes.

Dr. DEACON asked whether the broadening of the beam width at the shorter wavelength might not be due to the impulsive generation of small waves as the larger waves broke.

The Meeting closed at 11.55.

TENTH GENERAL MEETING OF THE ASSOCIATION

Monday, 20th September 1954

The Meeting opened at 14.10, when at the request of the President the Chair was taken by Dr. GOUGENHEIM. Twenty-eight delegates and guests were present.

H 8. The paper by MIYOSHI and AKIBA: «The tsunamis caused by the Myojin explosions» was read by title (see p. 238).

H 9. The paper by MIYOSHI: «Generation of the tsunami in the compressible water» was read by title (see p. 239).

H 12. The paper by TERADA, YASUI and ISHIGURO: «On the secondary undulation of Bay of Nagasaki» was read by title. (see p. 243).

H 13.1. Mr. WIEGEL read his paper: «Laboratory studies of gravity waves generated by the movement of a submerged body» (see p. 246).

Mr. URSELL: I have been particularly interested by Dr. Wiegel's remarks relating to the waves near the head of the disturbance (wave-front). If a wave is generated by a subsidence in the sea-bottom, a negative wave is generated at the front, but it appears from these experiments that it is soon overtaken by the crest following it. Results of this kind are of value to theoretical workers.

If the wave amplitude is so small that the linear theory is applicable, then the development near the front is obtainable by the method of JEFFREYS (Methods of mathematical physics, Cambridge 1946, p. 485). A comparison of this with the measurement of Dr. Wiegel should be interesting.

Mr. WIEGEL: A short distance from the origin of the disturbance a crest always appears prior to the first trough.

H 5. The paper by P. BERNARD: «Opportunité d'enregistrements de longue durée des ondes internes» was read by title (see p. 232).

C 4. On behalf of the Committee on oceanographical observations from Atlantic weather ships Commander LUMBY presented certain recommendations. These recommendations were adopted; they are printed in connection with the Report of the Committee (p. 98).

The Meeting closed at 14.50.

ELEVENTH GENERAL MEETING OF THE ASSOCIATION

Tuesday, 21st September 1954.

The Meeting opened at 8.30, when the Chair was taken by the President, Professor PROUDMAN. Thirty-two delegates and guests were present at the first part of the meeting; later on about fifty-five were present.

E 19. THE CHILEAN DELEGATION presented a proposal on «Natural Delimitation between the Pacific Ocean and the South Atlantic Ocean following the Arc of the Southern Antilles (see p. 178).
Owing to the absence of six months' notice, action on this recommendation was not possible at this General Assembly. It was left to the Executive Committee of the Association to consider the question. In a special meeting the same day the Executive Committee expressed its view as printed on p. 79.

B 1. The Secretary submitted his Report for the period 1951—54 (see p. 14). This was adopted unanimously.

B 2. Mr. HELGE THOMSEN submitted his Report on the activities of the Dépôt d'Eau Normale 1951—54 (see p. 19). This was adopted unanimously.

B 3. The Secretary submitted the Financial Report for the period 1951—54 (see p. 15). This was adopted unanimously.

B 4. The Secretary submitted the following Financial Estimates for the period 1954—57, proposed by the Executive Committee.

Average Expenditure for each Year:		
Standard Sea Water Service .....N. Cr.	5 000	
Bureau (incl. postage)	3 000	
Travel, officers AIOP	2 000	
Cost of publications	13 000	
N. Cr.	17 500	= 875£

These Estimates were adopted unanimously.

B 5. The Assembly then proceeded to the election of new officers and Executive Committee in accordance with the Statutes and By-Laws of the Association. On behalf of the Nominating Committee (p. 44) Dr. DEACON made nominations. The new officers and members of the Executive Committee were then unanimously elected as given on p. 8.

C 5. The report and recommendations of the Committee on preparation of technical handbook on physical oceanography printed on p. 100 were adopted.

D 5. It was agreed that the committee should continue its work. Dr. BÖHNECKE and Dr. GOUGENHEIM were elected members of the committee.

C 6. The report and recommendations of the Committee on questions concerning preparation of a bibliography were adopted (p. 101).

D 6. It was agreed that the Committee should continue its work and have the same members.

C 10. Dr. WISEMAN presented a report and recommendations of the Joint Commission on Oceanography. After a brief, but lively discussion, the decision was postponed.

D 9. In connection with the Symposium on Saturday, 18th September, the need for a Committee on current measurements had been indicated. This committee was established, with membership as given on p. 10.

E 18. Dr. SIMONPIETRI presented a proposal for establishing an Inter-American Oceanographic Institute. An abstract of this communication is printed on p. 176.

It was agreed that the Association might be represented on a Pan-American body with the above purpose, if so wanted. Professor R. H. FLEMING was appointed as representative. It was further announced that individual opinions on the matter,

f.inst. concerning the choice of locality for the institute, should be addressed to the Secretary of the Association for further elucidation.

H 14.1. Dr. EGGVIN read his paper: «Current conditions in the Norwegian Sea based on recent material» (see p. 252).

Commander LUMBY: Did Dr. Eggvin think that the forking of the North-going current through the Norwegian Sea into two parts was a regular feature of the circulation or was peculiar to one particular year?

Dr. EGGVIN: As far as suitable observations are available the main features of the current in the area considered are like those in the charts I showed. Especially this is the case concerning the current chart from 1954 which I showed in draft.

Dr. CARRUTHERS complimented Dr. Eggvin on the accomplishment of such a great piece of work and asked whether he had contrived so far to check any of his currents references by means of the ingenious employment of Ekman meters in the manner devised by him (Eggvin).

Dr. EGGVIN: During the last cruise I used the gear mentioned in measuring the current on the Miss Boyd Bank, near the Trænabank, on the Viking Bank and in the neighbourhood of Jan Mayen. Deepest observations 600 m.

H 19. Dr. TAIT read his paper: «Variations in the strength of the Atlantic Current in the Faroe-Shetland Channel» (see p. 258).

Dr. CARRUTHERS hoped Dr. Tait would be able to repeat his currents observations on the Wyville-Thompson Ridge because of his surprising result. When will his table of results be available so that one can examine them further side by side with the winds data of the recent German 1/2 century album atlas?

Dr. TAIT: It is the intention further to measure Faroe-Shetland Channel currents by current meter as soon as possible; the table of volume transports shown will be published soon.

Commander LUMBY supported Dr. Carruthers in congratulating Dr. Tait in having tested his zero current level by current measurements. One felt uncomfortable at times about accepting transport figures computed in this way, but there was a remarkable degree of consistency between the results of different workers. Was it not

possible, however, that great variations in current might be accompanied by great disturbance of the general system, and the level of zero current might change also?

Dr. TAIT: The assumption of zero current at the 35.00 $^0/_{00}$ isohaline, since partially verified experimentally by current meter measurement, was based originally on the circumstances 1) that in the region concerned there is the known situation of a northerly flowing water-mass superimposed upon one of radically different physical characteristics which is flowing in the opposite direction and therefore must surely be a region between them where there is no horizontal current, and 2) the concentration on numerous section diagrams between Faroe and Shetland of isotherms and isohalines on the 35 $^0/_{00}$ isohaline.

Dr. BÖHNECKE: Did Dr. Tait compare his values with those of Professor JACOBSEN gained by a similar method?

Dr. TAIT: My computations which are for sections at specific times are not strictly comparable with those of the late Dr. JACOBSEN which were based on composite approximately seasonal Faroe-Shetland Channel sections.

Professor SVERDRUP: The great merit of Dr. Tait's investigation is the use of *two* sections which permits ascertaining that the condition of continuity is fulfilled. The selection of the isohaline of 35.00 $^0/_{00}$ renders very satisfactory results, but the average values might perhaps be made identical by selecting a slightly different value, say 34.97 $^0/_{00}$.

As to the cause of the fluctuations it may be said that changes in the inflow may be caused by changes in the outflow from the Polar Sea. The problem is indeed complicated, but Dr. Tait is, I am sure, aware of this.

Dr. TAIT: Similar dynamic computation on the basis of zero-current at the 34.95 $^0/_{00}$ isohaline have in fact been made but no reliable agreement between the oceanic volume transports over the two sections was obtained, in this way. I agree, in fact it is my contention that similar dynamical assessments of not only the East-Icelandic Arctic water-mass, but also that issuing from the Baltic should be made.

H 18. Dr. ROMANOVSKY read his paper: «Les courants marins de surface dans le bassin occidental de la Méditerranée» (see p. 256).

Dr. ROMANOVSKY (on a question by Dr. CARRUTHERS): Les résultats obtenues par la méthode des flotteurs dérivants diffèrent, pour certaines régions, des résultats publiés par Nielsen. L'existence du tourbillon entre la France et la Corse n'a pas été signalée par Nielsen et le courant à l'ouest de la Sardaigne semble être en réalité inverse à celui figuré par Nielsen.

Professor SVERDRUP: I have had the opportunity to examine observations of temperature and salinity made by Dr. Trotti and the results of dynamic calculations. The data pertain to the Gulf of Genoa and the results are in perfect agreement with those shown by Dr. Romanovsky.

H 16. The paper by Dr. LA FOND: «On the circulation of the surface layers off the east coast of India» was read by title (see p. 254).

The Meeting closed at 12.00.

TWELFTH GENERAL MEETING OF THE ASSOCIATION

Tuesday, 21st September 1954.

The Meeting opened at 14.05, when at the request of the President, the Chair was taken by Dr. BÖHNECKE. Thirty delegates and guests were present.

H 15. The paper by HIDAKA: «Zonal currents driven by winds» was read by title (see p. 253).

H 25. The paper by HIDAKA: «Areas of divergence and convergence of wind stresses in the Pacific as the possible indicators of upwelling and sinking» was read by title (see p. 268).

H 31. The paper by LE FLOCH: «Recherches océanographiques au large des côtes de GUYANE et des bouches de l'Amazone» was read by Dr. ROMANOVSKY (see p. 278).

H 33. Commander LUMBY read his paper: «The depth of the wind-produced homogeneous layer in the oceans» (see p. 282).

Mr. von ARX: The region 10—20°W, 50—60°N which Commander Lumby has studied seems to me to contain the final link in a description of the circulation of the upper layers of the North Atlantic Ocean. *Fuglister's* chart of the temperatures at the 200 meter level in the North Atlantic suggests that surface water of the west wind drift must sink before making its way southward in the eastern North Atlantic and that the surface waters of the Norwegian Sea are not permanently in contact with those of the main North Atlantic immediately south of the Wyville-Thompson Ridge. I would like to ask Commander Lumby if he would comment on what he thinks may be happening in this very interesting part of the North Atlantic Ocean?

Commander LUMBY (in reply to Dr. Cooper and Mr. von Arx):

Sinking of the upper layer of water would occur in winter (February) because the layer is then unstable. But it seems unlikely that it can occur in autumn (November). The unexpectedly great depth of the layer in autumn appears, I suggest, to be due to advection. But it may also be the case that Rossby and Montgomery's theory does not make sufficient allowance for the effect of the wind when the stability of the water column is low.

H 38. The paper by UDA: «On the variation of water temperature due to the passage of typhoon» was read by title (see p. 297).

H 20. The paper by ABE: «A study of the foaming of sea water» was read by title (see p. 260).

H 28. Dr. JERLOV read his paper: «The use of the Tyndall effect for studying particulate matter in the sea» (see p. 270).

Dr. WISEMAN congratulated Dr. Jerlov on the work which he is carrying out on the particle size distribution in the water column above the deep sea floor. It would seem that such investigations will in the future give much useful information as to the suitability of any locality for the collection of long deep-sea cores. Owing to the immense labour involved in working up in detail a long core it was of particular importance to develop methods whereby cores which are likely to give the most information can be selected for detailed work.

H 4.2. The paper by JEAN LEGRAND: «Sur la recherche dans les archives anciennes de données sur les anciens niveaux des mers» was read by Dr. GOUGENHEIM (see p. 231).

H 28.1. Dr. JOSEPH read his paper: «The transport of suspended matter by tidal streams» (see p. 271).

Dr. CARRUTHERS asked whether the centrifuge used stripped the water to a point of complete clarity.

Professor SVERDRUP: Did the histogram of particle sizes apply to average conditions or to conditions encountered at a specific phase of the tide and at a specific depth? Have differences in particle distribution related to tides and depth been examined?

Dr. JERLOV: We have carried out similar measurements in a Swedish fjord studying the suspended matter by means of a tran-

sparency-meter. A linear relationship between the weight of the suspended material and the extinction was also found in this case.

Dr. Joseph: 1) Voraussetzung einer eindeutigen Beziehung zwischen Sinkstoffgehalt und Extinktionskoeffizienten ist, dass die mittlere Korngrössenverteilung (Korngrössenspektrum) konstant, also unabhängig von der Konzentration ist. Für viele See- und Flussmündungsgebiete ist dies zumindest zeitweile gültig. Doch ist eine laufende Kontrolle erforderlich. 2) Die Zentrifugenmethode bevorzugt natürlich das schwerere Material. Da aber der Sinkstoffgehalt in mg/l und nicht in Partikelzahlen angegeben wird, dürfte deshalb die Genauigkeit der Methode ausreichen.

H 37.1. The paper by R. Prasada Rao: «Annual cycles of beach erosion at Waltair on Bay of Bengal» was read by title (see p. 290).

H 37.2. The paper by M. Poornachandra Rao and C. Mahadevan: «The concretions near continental shelf off Visakhapatnam area» was read by title (see p. 292).

The Meeting closed at 14.00, whereafter an informal discussion on the Joint Commission on Oceanography took place.

THIRTEENTH GENERAL MEETING OF THE ASSOCIATION

Wednesday, 22nd September 1954.

The Meeting opened at 9.05, when the Chair was taken by the President, Professor PROUDMAN. Thirty-five delegates and guests were present.

H 32. Professor Y. LE GRAND read the paper by LE GRAND, LENOBLE and SAINT-GUILY: «La pénétration de l'ultraviolet dans la mer» (see p. 280).

H 34 Dr. LUMBY read the paper by LUMBY and FOLKARD: «Variations in the surface tension of sea water *in situ*» (see p. 284).

Dr. LONGUET-HIGGINS: Water waves tend to produce second-order drift-currents which are forwards at the bottom and at the free surface and backwards at intermediate levels. This probably accounts for the shorewards motion of the slicks which Commander Lumby observed.

Dr. CARRUTHERS raised the question whether the presence of the boat could have caused interference with the continuity of a film.

Commander LUMBY: Ewing has referred to the fact that the passage of a boat will compact the surface film; smoother areas are seen in the wake. In our measurements the boat was stopped and the consistency of the results in ruffled water suggests that the measurements of spreading force were not affected by the boat.

I had no experience of «slicks» caused by fresh water overlying salt water. The difference between the spreading force of our solutions on sea water and on fresh water being only about 7 %, the standards we used are hardly fine enough to distinguish such a difference.

H 24.1. Professor EMERY read his paper: «Nutrient budget in the ocean» (see p. 265).

Dr. MORTIMER: Are the figures for annual use by phytoplancton based on G. A. RILEY's figures for oceanic phytoplancton production? If so, account should be taken of STEEMANN-NIELSEN's recent estimates which are of the order of 1/10 of those of RILEY's. See recent papers and correspondance in Journ. Cons. Intern.

Mr. DAY: What was the likely accuracy of the estimate of phosphorous? It seemed that phosphorous was very irregularly deposited over the ocean floor and there was no certainty that we knew as yet exactly how it was distributed.

Professor EMERY: 1) RILEY's figure for phytoplancton crop is 700—800 gr/m² for open sea. I used 1000 to include near shore areas. 2) P in sediments was based on per cent P in Atlantic and Pacific off shore pelagic sediments and P in blue and green muds in nearshore areas. Both figures were weighted according to areas covered. Phosphorite was ignored owing to relatively small area of distribuiton as compared with the loose sediments.

H 35. The paper by MENACHÉ: «Simplification de la Table de titration de Martin Knudsen pour la détermination de la chlorinité de l'eau de mer» was read by title (see p. 286).

H 24. Mr. DAY read his paper: «The physical characters of some deep sea oozes» (see p. 264).

Dr. KOCZY: 1) Dr. Kullenberg has improved the sampler and taken rock samples in the Baltic. 2) The transport from the rises to the basin can also be explained by the prevention of sedimentation, as the study of sediments by Dr. C. W. CORRENS has shown.

Mr DAY: 1) We believe that the bottom rock surface is too hard to be broken by a simple blow from a corer . 2) It seems most probable that both methods of sediment transport will operate.

Dr. DIETZ: From three points of view, there is marine geological evidence for currents in the abyssal ocean. These are 1) clear rock surfaces which are apparently kept swept clean of sediment, 2) the profile of the bottom as shown by the echo sounder indicating deposition localized in basins, and 3) bottom photographs which have shown oscillation ripples in globigerina oozes at a depth of

a mile and scours shown in red clay at 3025 fathoms (DAVID OWEN's photo near Bermuda)

Mr. DAY: The evidence for localised currents on the ocean bottom is growing, and we would welcome information from the dynamical oceanographers on the possible mechanisms.

Dr. CARRUTHERS asked whether they had used devices to give the ratio core length to penetration. Had he done petrological thin slide investigations to see whether there were pebbles of microcline?

Mr. DAY: 1) Penetration of the corer was estimated from the distribution of mud on the outside of the core barrel. 2) No thin sections had been made yet.

Dr. WISEMAN said how pleased he was that this work was now being undertaken at Cambridge; and he hoped that more of this work would be undertaken. There were two questions. 1) Had Mr. Day undertaken any foraminiferal investigations with the object of determining the gradual change to the glacial layer? 2) Had Mr. Day undertaken any geochemical work?

Mr. DAY: 1) It is hoped to study the foraminifera of the cores obtained from the ocean basin deeper than about 4000 meters. 2). No geochemical investigations could be made with the equipment available. Some of the latest cores collected were suitable for this type of investigation if any worker wished to have samples.

Dr. COOPER asked whether the phosphate was an apatite and if so which one, fluoro-carbonato- or hydroxy-apatite. This knowledge is highly significant for physico-chemical understanding of the processes of deposition.

Mr. DAY: The phosphate was a dark amorphous lump most probably collophane. Spectrochemical work would need to be carried out to determine the finer details.

The Meeting closed at 10.35.

FOURTEENTH GENERAL MEETING OF THE ASSOCIATION

Wednesday, 22nd September 1954.

The Meeting opened at 14.05, when at the request of the President, the Chair was taken by Professor REVELLE. Forty-three delegates and guests were present.

H 26. Dr. HILL read his paper: «The Topography of the mid-Atlantic Ridge» (see p. 269).

H 29. The paper by KULLENBERG: «The salinity of the interstitial water in recent sediments» was read by Professor PETTERSSON (see p. 272).

H 30. The paper by LAURENT: «Sur quelques phenomènes particuliers observés au cours des campagnes d'océanographie et d'hydrographie littorales» was read by Dr. GERLIER (see p. 274).

H 37. The paper by POSTMA: «Transport of suspended matter in estuaries» was read by title.

H 39. Dr. WISEMAN read the paper by WISEMAN and SMALES: «Significance of nickel and cobalt contents of deep-sea deposits and of sea-water» (see p. 299).

Remarks were made by CARRUTHERS, EMERY, FLEMING, HILL, KOCZY, LONGUET-HIGGINS, MORTIMER, MUNK, PETTERSSON, REVELLE, WIEGEL and WISEMAN.

The Meeting closed at 16.15.

FIFTEENTH GENERAL MEETING OF THE ASSOCIATION

Thursday, 23rd September 1954.

The Meeting opened at 10.20, when at the request of the President, the Chair was taken by Professor SVERDRUP. Forty-five delegates and guests were present. The President, the Secretary and the Deputy Secretary had to participate at the Meeting of the Executive Committee of the Union during most of this Meeting.

C 10. Dr. WISEMAN read a revised report of the International Joint Commission on Oceanography. After some discussion a proposal by Dr. DEACON was accepted. In accordance with this the Report of the Joint Commission was adopted as printed on p. 109.

D 10. It was agreed that the representatives of the Association, i. e. of the Union, on the Joint Commission should be the the same as before.

C 3. The report of the Committee on nomenclature of ocean bottom features, printed on p. 97, was accepted.

D 3. It was agreed that the Committee on nomenclature of ocean bottom features should continue its work with members as given on p. 9.

C 9. The terms of reference of the committee on current measurements were adopted as printed on p. 13. A report on the results of the preliminary considerations of the committee is printed on p. 107.

C 8. The provisional committee on storm surges, established on Tuesday, 14th September (see D 2, p. 30), presented a report (see p. 105). This report was adopted.

D 8. The committee on storm surges was established, with members as given on p. 10.

E 1. The British national report was read by title (see p. 111).
E 2. The Canadian national report was read by title (see p. 121).
E 3. The German national report was read by title (see p. 123).
E 4. The Spanish national report was read by title (see p. 131).
E 5. The Finnish national report was read by title (see p. 134).
E 6. The Indian national report was read by title (see p. 136).
E 7. The Indian tidal report was read by title (see p. 143).
E 8. The Irish national report was read by title (see p. 146).
E 9. The report on oceanography in Texas was read by title (see p. 147).
E 10. The report on the activities of the Service Hydrographique of the International Council for the Exploration of the Sea was read by title (see p. 148).
E 11. The report of the University of New York was read by title (see p. 150).
E 12. The report of the University of Washington was read by title (see p. 154).
E 13. The Argentine national report was read by title (see p. 155).
E 14. The Philippine national report was read title (see p. 161).
E 15. The Italian national report was read by title (see p. 163).
E 16. The report of the institute «F. Vercelli», Trieste, was read by title (see p. 170).
E 17. The report on tidal research, Trieste, was read by title (see p. 173).
H 36.1. Professor PICOTTI read his paper: «Unità di misura nelle ricerche chimico-fisiche-talassografiche» (see p. 288).
H 37.3. Dr. SHALEM read his paper: «Le plateau continental est Mediterranéen» (see p. 294).
H 24.2. The paper by FAGE: «Teneur en O_2 de l'eau au voisinage du fond» was read by Dr. Tchernia (see p. 266).

The Chairman expressed the Association's thanks to the retiring President and to the retiring Secretary for their valuable work.

The Meeting closed at 12.05.

REPORT OF THE PRESIDENT TO THE GENERAL ASSEMBLY OF THE UNION

25th September 1954.

In the three years between the General Assemblies at Brussels and at Rome the six scientific committees of the Association worked continuously. This work produced a publication on mean sea-level data; a memoir on the secular variations of mean sea-level, ready for publication; a bibliography on tides, ready for publication; and a report on the oceanographical work on all ocean weather-ships, nearly ready for publication. These committees have been reappointed and three new ones have been created. The new committees are on the methods of measuring currents, on the collection of data for the study of storm-surges, and on the preparation of an oceanographical programme for the International Geophysical Year.

In this General Assembly fifteen full sessions have been held, each occupying half a day. During these sessions 62 scientific communications were received in full and followed by lively discussions. Up to the present time the Association has not found it necessary to organise its scientific sessions into different series which are taken at the same time, but it has been able to take all its communications in one series. This means that every delegate and guest attending our sessions has been able to hear every communication.

Four half day sessions were devoted to a symposium on storm-surges to which the Association of Meteorology was invited, one long session to a symposium on methods of measuring currents, and two sessions to communications on waves, which in fact constituted a third symposium. The organisation of symposia is a leading feature of the work of the Association, and this tends to give a particular character to each General Assembly; a character which changes from one General Assembly to the next. For example,

at Brussels the chief topics of discussion concerned the ocean-floor and its vicinity, but here in Rome the chief topics have been the different forms of the motion of sea-water. We have, however, devoted three half day sessions to the physical and chemical aspects of oceanography. We have also received a number of very interesting national and institutional reports.

A recommendation was received from the Chilean delegation, regarding the divisions between the oceans and seas. Owing to the absence of six months' notice, action on this recommendation has not been possible at this General Assembly, but steps are being taken by the Executive Committee of the Association to lead to such action as seems best.

The only recommendation of our Association which comes before the Union concerns the International Joint Commission on Oceanography. It is recommended that the Joint Commission be reappointed on the same terms as before and with the same membership as before.

The Officers of the Association and the members of the Executive Committee for the next period are as given on p. 8.

REPORT OF THE EXECUTIVE COMMITTEE ON THE CHILEAN PROPOSAL REGARDING THE DIVISIONS BETWEEN THE OCEANS AND SEAS

On the 21st of September 1954, at a Special General Assembly of the A.I.O.P., the Chilean Delegation presented information previously submitted in «Delimitacion Natural entre los Oceanos Pacifico y Atlantico sur por el Arco de las Antillas Australes». The request that the A.I.O.P. consider the proposals contained in this document was again reviewed at a meeting of the Executive Committee of the Association held on the 23rd of September.

The document contains six General Recommendations and one Specific Recommendation. The General Recommendation d) «suggests to the sponsoring states the preparation of bathymetrical maps of the surrounding seas in order to put up to date the Bathymetrical World Map». This is in full accord with the expressed interest and efforts of the Association and is, therefore, strongly endorsed. The other General Recommendations, that the delimitation of oceanic systems and of seas be based upon scientific-geographical antecedents, would involve elaborate studies by physical oceanographers, marine biologists, geologists, geographers and possibly scientists from other fields. The responsibility of obtaining wide and general agreement among such a large group concerning the bases for such natural delimitations between oceans and seas might fall upon I.C.S.U. or the International Geographical Union.

From past experiences with problems of this kind the Executive Committee of the Association believes that it would be virtually impossible to obtain unanimous agreement among scientists representing so many fields of knowledge. If, however, an effort should be made along the lines indicated above, the A.I.O.P. would appreciate being kept informed.

The Executive Committee of the Association desires it to be known that they recognize the high quality of oceanographic work now being conducted by Chile and that the exhaustive studies represented by their document illustrates the active interest of the scientists of Chile in the problems of the seas. Because of the valuable material contained therein, it is believed that the complete document would be of interest to the Pan-American Institute of Geography and History.

GENERAL RESOLUTION

Adopted by the General Assembly of the Union on the 25th September 1954, on the recommendation of the Association

In view of the fact that under existing statutes the *Joint Commission on Oceanography* can only exist in its present form for approximately three years, it is considered desirable to lay plans for the continuance of its work after that time by some other suitable body. It is accordingly recommended that the Joint Commission on Oceanography be reconstituted to further the work which it is already doing.

In the remaining three years consideration will be given to what form the future body should take in order to avoid overlapping.

GENERAL RESOLUTION

Adopted by the General Assembly of the Union on the 25th September 1954, on the recommendation of the following committee, appointed on the 14th September: J. Proudman (U.K.), R. Stoneley (U.K.), H. Mosby (Norway), M. Ewing (U.S.A.).

The International Union of Geodesy and Geophysics:

1) notes the terms of the draft articles on the continental shelf adopted at the Fifth Session of the International Law Commission;
2) views with alarm the possible consequences to fundamental research in the geophysics and submarine geology of the seabed and subsoil of the continental shelf and in the physical oceanography of the waters above the shelf;
3) asserts that fundamental research by any nation carried out with the intention of open publication is in the interest of all;
4) requests the International Council of Scientific Unions to transmit, through the appropriate channels, the substance of this resolution to the General Assembly of the United Nations at the earliest opportunity;
5) expresses the hope that the Assembly will so amend the draft articles before they become law so as to ensure that such fundamental research at sea may proceed without vexatious obstruction.

In making this Resolution the International Union of Geodesy and Geophysics adds the hope that no institution or individual will carry out investigations on or over any continental shelf without first entering into friendly relations with the corresponding institution of the relevant coastal State.

For Recommendations adopted by the Association, see pp. 30, 31, 35, 62, 63, 64, 75, 92, 94, 99, 101, 102, 103, 104, 106, 109.

PRESIDENTIAL ADDRESS

THE UNKNOWN TIDES OF THE OCEANS

By
J. PROUDMAN

I propose to discuss the problem of the determination of the tidal rise and fall of the surface of the oceans.

It is probable that, at some time in the future, instruments will be constructed and operated which measure these motions, but up to the present time this has not been done. Pressure-gauges, notably those of Favé and Rauschelbach, have been constructed, but they have only been successfully operated in relatively shallow seas.

A method depending on the tidal analysis of barometric observations taken over the oceans has been put forward by Barkow (1911) and Bartels (1926), but has not been successfully employed, and to me the difficulties involved in this method seem very great.

Up to the present time it is only from observations taken near land, and from the dynamical principles which are known to govern the tides, that knowledge of the tides in the open oceans has been derived. The difficulties in applying these dynamical principles are so great that the leading features of the tides have not yet been determined in any really convincing way. Considerable progress has been made with the Atlantic Ocean, and a little progress with the Indian Ocean, but practically none with the Pacific Ocean.

I shall find it convenient to refer to certain *harmonic constituents* of the tides. Such a constituent is a part of the resultant motion in which the rise and fall of the ocean-surface is a simple harmonic function of the time. Particular harmonic constituents are M_2, the

principal semi-diurnal constituent due to the moon, and K_1, the diurnal constituent due to both the moon and the sun.

I shall also find it convenient to refer to *cotidal* and *co-range lines*. A cotidal line is one at every point of which high water occurs at the same time; a co-range line is one at every point of which the range of tide is the same. A particular harmonic constituent of the tides may be regarded as known for any region of the ocean when a chart showing both cotidal and co-range lines has been justifiably constructed for the region.

I will first refer to those *hypothetical* charts of cotidal lines which have been constructed from a knowledge of observations on the coasts of continents and islands by simple interpolation from coast to coast.

The first were those of Whewell, published as long ago as 1833 and relating to the resultant semidiurnal tides on the days of new moon and full moon. These charts contain no amphidromic regions; but in 1936 he introduced such a region into the southern part of the North Sea, and so it has remained in the latest charts.

The next were those of Harris, published in 1904, and relating to the mean semi-diurnal tide. These differ radically from those of Whewell and I shall refer to them again in connection with dynamical theory. They contain a number of amphidromic regions; those in the middle of the North Atlantic and in the north-west of the Indian Ocean have remained a feature of the later chartes.

The next charts for the oceans were those of Sterneck, published in 1920 and 1921, and relating to the M_2 and K_1 harmonic constituents. For the Pacific Ocean these differ very seriously from those of Harris, though for the North Sea they contain, for the first time, the three amphidromic regions which are a feature of the latest charts.

In 1944 Dietrich proposed cotidal charts for the harmonic constituents M_2, S_2, K_1, O_1 and in 1951 Villain gave cotidal charts for the M_2 constituent. Both these authors emphasise the hypothetical nature of their lines over large areas of the oceans.

It is to be noticed that none of the charts to which I have referred contain any co-range lines, so that they only relate to the *times* of the tides and not to their *heights*.

The tides are theoretically determined from a knowledge of the shapes and sizes of the basins and from a knowledge of the gene-

rating forces. A certain amount of general mathematical work has been done on the problem so presented, but owing to the enormous complication of any process aiming at a numerical solution, such a solution has not yet been attempted. One mathematical theorem which may be called the «resonance-theorem», expresses the distribution of tides over the oceans as a series of multiples of the distributions in the possible free oscillations. This theorem shows that when the period of the generating forces is near to that of one of the free oscillations (eigen-values) then the distribution of the forced tides is similar to that of the particular free oscillation. In 1900 Harris gave a theory of the distribution of the tides which depended on this theorem. Considering the M_2 constituent, he assumed: 1. That the tides are dominated by the forms of simple free oscillations which have the period of this constituent; 2. That these forms may be determined without reference to the rotation of the earth; 3. That these forms may be determined for separate regions of the oceans, without paying any attention to the absence of coasts parallel to the currents.

Though it is permissible to entertain very serious doubts about the validity of the details of Harris's arguments, yet it is remarkable that the latest of the charts already referred to, constructed nearly 50 years after those of Harris and using many more observations than were available to him, do not differ very seriously from his in any major respects as regards the main oceans, but only for such restricted regions as the North Sea. In 1939 Prüfer considered the distribution of the constituents M_2, S_2, N_2, K_2, K_1, O_1, P_1 over the Indian Ocean. He first calculated the tides in certain simple canals having dimensions suggested by parts of that ocean, and then used these results as a general guide in drawing both cotidal and co-range lines from coastal data. His work may be regarded as an extension of that of Harris, and his charts are notable as being the first to contain co-range lines for an open ocean.

Up to the present time, the actual determination on dynamical principles has been most satisfactorily carried out for such narrow elongated basins as the Adriatic Sea and the Red Sea, where the currents are always sensibly in the direction of the length of the basin. This was done by Defant and Sterneck between 1913 and 1919, and the scheme of calculations may be referred to as the «narrow sea theory».

Between 1924 and 1932 Defant attempted to extend the application of the narrow sea theory to the Atlantic Ocean, the basin of which is certainly elongated. His calculations probably give an approximation to the conditions on the central line of the ocean, but do not constitute a guarantee of this, and do not provide a satisfactory determination of the tides over the whole of the ocean.

The narrow sea theory makes use of a minimum amount of information based on observation, but even in this case, the calculated times and heights are determined much more by observations than by the generating forces, viz. by observations at the openings into the oceans.

Naturally, work has been done in which full use has been made of all the observational information available.

I will first refer to the construction of charts of cotidal and co-range lines from observations of tidal currents over the region in question and from observations of tidal heights along such coasts as form part of the boundary of the region. From a knowledge of the currents, the dynamical equations lead to the directions of the cotidal and co-range lines. From a knowledge of such directions over the whole region, it is possible to draw the lines over the whole region, but not to associate figures with them; and then, from the known coastal values, the particular times and ranges associated with each line which strikes a coast can be determined. The actual calculations for the M_2 constituent of the tides of the North Sea were carried out by Doodson in 1924 and for the tides of the English Channel and Irish Sea by Doodson and Corkan in 1931.

The application of this method to the deep oceans is made very difficult by the difficulty of securing observations of tidal currents of sufficient accuracy in sufficient numbers. The speeds of the currents are very small and the occurrence of internal tides makes it necessary to take observations at many depths at each station, as it is the depth-mean of the current which is required.

Turning now to the problem of calculating the tides over a region from observations of tidal heights along the coasts only, I will first mention a process used by Grace from 1932 to 1935, but which only applies to limited regions of suitable shapes, partially bounded by coasts. It consists in replacing such a region by a number of rectangles so that the number of sides along coasts is at least equal to the number of external sides in the open ocean. The

depth of water over each rectangle is taken to be uniform, and the fundamental differential equations are solved so as to obtain relationships between the mean heights and mean normal currents along its sides. Across each side of a rectangle a uniform normal component of oscillating current is assumed and the mean oscillation of height along each side is then calculated as due partly to that in a closed basin of the same dimensions and partly to the currents across the sides. This mean height-oscillation along each side is taken to be the height oscillation at the mid-point of the side. After equating the values of the height-oscillations obtained from two different rectangles at a common mid-point, all the heights can be expressed in terms of the external currents. On using the values of the heights obtained along the coasts, the currents across the open sides may be found, and then the tides over the whole region may be found. In 1932 and 1933 Grace applied this method to the Gulf of Mexico, first to the K_1 constituent, and then to the M_2 constituent, and in 1935 he applied it to the M_2 constituent of the Bay of Biscay. In all three cases he produced charts of both cotidal lines and co-range lines.

In 1944 I made a study of the dynamics of the M_2 constituent of the tides of the South Atlantic Ocean. Taking advantage of the special shape of the basin of this ocean, I applied to each band of the ocean covering 5° of latitude a mathematical theorem relating to a channel. Using observed values of tidal heights along the coasts, I constructed a chart of both cotidal and co-range lines over part of the ocean. Owing to the special nature of the mathematical method, it is not suitable for continuous refinement so as to allow for all the details of the basin, and therefore I have not continued it beyond a first approximation.

I will now review the work of Hansen during the years 1940 to 1952. He took a network of squares over the region of the ocean in question and considered the tidal heights at each point of the network. He replaced the fundamental second order differential equation for tidal heights by a difference-equation so that the height at any internal point of the network may be expressed in terms of the heights at the four nearest points of the network. As there is then one linear algebraic equation for each internal point of the network, the tidal heights at all the internal points may be found in terms of the tidal heights at all the external points

of the network, i. e. at all the points on the boundary of the network.

At those boundary points which are near to a coast the tidal heights are known from observation, and Hansen appears to have made an independent inference of the heights at those boundary points which are not near to a coast. If the length of a side of the network is sufficiently small, the coastal condition will provide an extra equation for each coastal boundary point. It follows that, if at least half the boundary points of the network are coastal points, the tidal heights at all points, including the non-coastal boundary points, may be found from the coastal observations.

The adequacy of the use of difference-equations requires the length of a side of the network to be small, and this involves a large number of points in the network. The arithmetical process of solving the equations may then present difficulties due to the existence of the periods of possible free oscillations already mentioned.

In 1948 Hansen applied his method to the M_2 constituent of the tides of the English Channel and the North Sea, solving the equations by a method of successive approximations. Starting with an approximate knowledge of the tides over these regions, obtained very much as Doodson constructed his charts, he used the difference-equations to produce a better solution. He published the details of his calculations for the North Sea in 1952. His network covered the central part of the sea, and had 21 internal points and 18 boundary points; he evaluated 12 successive approximations.

In 1949 Hansen applied the method to the M_2 constituent of the tides of the North Atlantic Ocean, using a network with 17 internal points and 10 boundary points. Five of these boundary points are in the open ocean, and for the tidal heights at these he used observations of tidal currents. In this case I do not know whether Hansen assumed an approximate knowledge of the tides over the ocean and then used the method of successive approximations, or whether he used a direct arithmetical solution of the equations. It is much to be hoped that he will publish many more details of his calculations, as he has done for the North Sea. In each case Hansen constructed charts of contour lines of the tidal heights at two phases differing by a greater period, and these, of course, are equivalent to charts of both cotidal lines and co-range lines.

In 1952 Hansen published a cotidal and co-range chart for the whole of the Atlantic Ocean, and this may be regarded as the best that has yet been done for any ocean. I have no reason to doubt that this chart gives a true picture of the M_2 constituent in the Atlantic Ocean, but I assert that no really convincing justification has yet been published.

In 1953 Doodson and Rossiter completed a calculation which had been begun by Corkan and in which a network of points and difference-equations, as in Hansen's work, are used. It relates to the M_2 constituent in the Irish Sea. Starting with the observed coastal values of the tidal heights only, and using the coastal conditions, the mathematical process known as «relaxation» is employed so as to approach to a solution of the difference-equations. This work is important as showing what can be done from coastal heights only, though the resulting cotidal and co-range chart is inferior to that of 1931 which was based on much more observational material, viz. tidal currents.

Finally, I mention a calculation quite different from any of the foregoing. It is a calculation of the K_2 constituent of the tides along the equator in the Indian Ocean, carried out by Fairbairn and based on a knowledge of the tide-generating forces and of the observed tides along the coasts of that Ocean north of the equator. It is the first application of a theorem which I published in 1925. Fairbairn's chart is in general agreement with the M_2 charts for the Indian Ocean already referred to, but this time there is much more justification.

One factor which has not been adequately allowed for in any of the dynamical treatments relating to the open oceans is the effect of *earth-tides*, and yet this effect is important.

The results which have been presented for certain *seas* I regard as reasonably justified, and I consider that the leading features of the tides of these seas are known. But in taking the title of this address as «The Unknown Tides of the Oceans» I have in mind the absence of complete justification of the results presented for the great *oceans*.

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Reports of Scientific Committees

C 1

REPORT OF COMMITTEE ON TIDES

by

J. PROUDMAN

Secretary.

The Committee suffered a severe loss by the death of its Chairman, Mr. H. A. Marmer, on 5th November 1953.

All members of the Committee have worked on the Bibliography, and valuable assistance has also been given by the Director of the United States Coast and Geodetic Survey, by Ir. Schijf of the Netherlands Rijkswaterstaat and by Professor Hidaka of Tokyo.

It is hoped that the Bibliography will be completed and ready for presentation to the General Assembly of the Association at Rome. It consists of a list of publications on the Tides of the Ocean, in a Latin or Teutonic language. It is arranged chronologically as regards years of publication, the earliest year listed being 1665 and the latest 1939. It is followed by an Index in which the names of authors are given alphabetically. The subjects treated in each publication are indicated by numbers in the Universal Decimal Classification.

At Rome the Secretary will tender his resignation. The Association may wish to reappoint the Committee so that it may prepare a similar bibliography for the years subsequent to 1939.

C 2

REPORT OF COMMITTEE ON MEAN SEA-LEVEL AND ITS VARIATIONS

By

A. T. DOODSON

Secretary

At the General Assembly in Brussels, August 1951, the Executive Committee appointed Dr. R. H. Corkan as Secretary and Mr. L. P. Disney and Mr. J. Egedal as members of the Committee on Mean Sea-Level and its Variations, under the Chairmanship of Vice-Admiral J. D. Nares. As a result of Dr. Corkan's untimely death in 1952, the Executive Committee appointed Dr. A. T. Doodson to be Secretary.

1. Mean Sea-Level Volume.

The Committee is empowered by the Association to prepare and to submit to the Secretary of the Association, with a view to publication, a collection of mean sea-level data at intervals of five years. A large amount of information has been collected by the International Hydrographic Bureau, and this has been collated by Mr. Rossiter, senior assistent at the Tidal Institute. The results are now in print as Publication Scientifique No. 12, the third volume in the series, and while it primarily contains data for the years 1947—1951, it also contains much unpublished data for earlier years, as well as many important corrections to Publications Scientifiques Nos. 5 and 10.

The Committee wishes to express its cordial thanks to the International Hydrographic Bureau and to the many national authorities who have actively collaborated in this work.

2. Secular Variations.

At the Brussels meeting the Committee was authorised to undertake a study of secular changes in sea-level, the Secretary and two

members to take a specified region each. A questionnaire was prepared for completion by tidal authorities. Both Mr. Egedal and Mr. Disney have completed investigations into the variations over their allotted areas, and their findings will be reported to the Conference with a view to publication.

For a number of reasons, no results are available for the area covered by the Secretary. Paucity of data delayed an immediate start to the work, and little progress had been made when Dr. Corkan died.

Ill health prevented the present Secretary furthering the work before information was recieved from Mr. Disney and later from Dr. Munk that the latter, with his colleagues, had already investigated all the data published by the Association, and so they had covered what had been intended by the Committee. It was judged wise to await the publication of the investigation before undertaking further work by the Committee, especially as a year hence further observations would be available.

3. *Geophysical Year.*

The Committee proposes that:

In order to widen our knowledge of the secular variation of the sea-level it is desirable that tidal observations should be obtained during the Geophysical Year 1957—58 and in later Geophysical Years at the stations set up in the regions where such observations are lacking. The observations should be referred to a durable fixed datum easy to find again, and should be accompanied by observations of the barometric pressure.

Appendix 1.

Summary of report by J. Egedal on secular variations of mean sea-level (Europe, except British Isles, and North Africa).

It has not been possible to provide reliable data for Iceland, Northern Norway, Yugoslavia, or U.S.S.R., and no data have been obtained from Poland or Turkey.

The tables give details of secular variation for individual sta-

tions, and the following mean values for countries may be derived, in units of 0.01 cm per year.

Sweden	— 44	Greenland	+ 33
Finland	— 56	Netherlands	+ 15
Latvia	+ 8	France	+ 14
Germany	+ 12	North Africa	+ 4
Denmark (except Greenland)	+ 5	Portugal	+ 15
		Italy	+ 17

In Scandinavia the maximal sinking of sea-level is found in northern Sweden (latitude 65°). Along the Swedish Coast (towards SSW) the sinking is slowly diminished, but at the coast of northern Norway in latitude 65° the sinking is diminished much more and the same is the case for Latvia, where the sinking is changed into a slight rising.

The report discusses the many factors which affect the sea-level, and special reference is made to the difficulty of observing values for the eustatic variation. The effects of folding processes of the earth's crust, variations up great rivers and near volcanoes, are briefly mentioned. The greatest variations are found in higher latitudes.

Appendix II.

Summary of Report by L. P. Disney on secular variations of mean sea-level. (America, Hawaiian and Philippine Islands, and Japan).

The tables are given only for places where the observations extend over a period of at least 17 years. Basing results on those places where the series of observations cover yearly values of 25 years or more the relative variation of sea-level in various regions are summarized below, in units of 0.01 cm per year.

Canada (north of lat. 46° 30' N) and Alaska	(slight fall)
Canada (south of lat. 46° 30' N)	28
United States (Atlantic coast)	39
United States (Gulf coast)	55
United States (Pacific coast)	15
Canal Zone (Atlantic end)	12

Canal Zone (Pacific end)	:	15
Argentina (Buenos Ayres)	:	11
Argentina (Mar del Plata)	:	0
Argentina (Quequen)	:	—10
Hawaiian Islands	:	21
Philippine Islands	:	14
Japan	:	10
Formosa	:	22

It will be noted that except for two entries the level of the sea is rising. Results for the coasts of the United States show marked differences for different series of years, so that for a true comparison of results for various places the result should be derived from approximately the same years of observations.

C 3

REPORT OF COMMITTEE ON NOMENCLATURE OF OCEAN BOTTOM FEATURES

By

J. D. H. WISEMAN

Chairman

Since the IXth General Assembly at Brussels the Committee has held two meetings, one at the International Hydrographic Bureau, Monaco, in September 1952 and the other at the University, Liverpool, in August 1953. A further meeting has been arranged to take place in Monaco in September of 1954, immediately preceeding the Xth General Assembly at Rome.

The work of the Committee has been considerable and a form of definitions of deep-sea features has been finally agreed by it and was published in 1953 (Wiseman and Ovey, 1953, "Definitions of Features on the Deep-sea Floor", *Deep-sea Research*, Vol. 1, pp. 11—16).

Work is in progress on the naming of features in the different oceans and the Committee has asked the British National Committee to publish proposed names. Those for the Pacific, Indian and Southern Oceans should be published in time for consideration by the International Committee at Monaco in September, and possibly also those for the Atlantic Ocean.

C 4

REPORT OF THE COMMITTEE ON OCEANOGRAPHICAL OBSERVATIONS FROM ATLANTIC WEATHER SHIPS

By
J. R. LUMBY
Chairman.

The amount of work undertaken in the past three years by Ocean Weather Ships in the North Atlantic has been maintained at about the same level as formerly. Although the States concerned have co-operated to some extent in carrying out the work, an international programme has not yet been established. In February 1954, fresh arrangements for the occupation of the Ocean Stations were made at the conference of I.C.A.O. (International Civil Aviation Organization). Under the original scheme individual Stations were for the most part occupied by the ships of a particular State, but the new plan, which operates from 1st July 1954, involves the European ships in a wider circulation among the Stations. In consequence, some form of international programme may prove essential, if the work is to continue. Furthermore, the network of Ocean Stations may serve as a basis for an international programme of oceanography to be carried out during the Geophysical Year 1957–8.

With these possibilities in mind, detailed inquiries have been made about the equipment of the ships for oceanography, the work which has so far been done, and the extent to which the data obtained have been published or reported on. These enquiries covered both the Pacific and the Atlantic Oceans, and the resulting information is embodied in a report appearing as a Scientific Publication. It emerges from the report that the capacities of the ships for undertaking oceanographical work differ considerably, and that

the limitations, especially of the smaller ships, must to a large extent determine the nature of the international programme which can be expected to operate successfully.

The Association was invited by I.C.A.O. to send a representative to the conference held in Paris in February 1954. Professor le Gall was nominated by A.I.O.P., as a member of the Committee on Weather Ships, but it was with great regret that the news of his death was received shortly before the conference began. Through the courtesy of I.C.A.O., arrangements were made for Professor le Gall's place to be taken by the Chairman of the Committee, who was present for a short time during the closing stages of the conference. The resolutions and other actions relating to oceanography, which were accepted by the conference, are given in the Chairman's report mentioned above.

Recommendations.

1. The Committee recognize that a variety of oceanographical work is being done in the Weather Ships of different States, but consider that in view of the differences in the capacities of the ships, it is not feasible to establish an elaborate programme on an international basis.

2. The Committee therefore recommend that as a contribution to the oceanographical programme arranged for the Geophysical Year, the States operating Weather Ships in both Atlantic and Pacific Oceans be asked to include in their existing programme the observation of temperature by means of Bathythermographs, lowered to 450 feet once a day on station and every 6 hours on passage to and from station, the records to be accompanied by relevant meteorological data and sea surface temperatures taken by thermometer.

3. The Committee notes that a central collection for these records can be established if the B/T slides are sent to the U. S. Hydrographic Office, where they would be photographed.

4. The Committee appreciate the fact that biological observations may also help in distinguishing water masses and recommend that if enquiry shows it to be practicable, biological observations be similarly arranged.

C 5

REPORT OF COMMITTEE ON PREPARATION OF A TECHNICAL HANDBOOK ON PHYSICAL OCEANOGRAPHY

By
H. U. SVERDRUP
Chairman

Of the five sections of the contemplated Handbook only one has been completed, the section by Mr. C. E. LaFond: «Processing oceanographic data» which was issued by the U. S. Navy Hydrographic Office in 1951 as H.O.Pub. no. 614.

The prospect of completing the other sections is not very bright. Before the next meeting of the AIOP the committee must decide whether to recommend to go on with or to abandon the original ambitious plan. In the meantime the possibility exists that an elementary book on methods in physical-chemical oceanography may be prepared by one single person whose manuscript will be critically examined by the committee before its publication. The committee is willing to render such assistance, believing that there is a definite need for a book of that kind and that it is a proper task of the AIOP to help towards producing it.

C 6

REPORT OF COMMITTEE ON QUESTIONS CONCERNING PREPARATION OF A BIBLIOGRAPHY

By
H. U. SVERDRUP
Chairmann.

a. Bibliography.

1. The Committee recommends that «Bulletin Analytique», Section II Physique du Globe and «Science Abstracts» be included in the mailing list of any periodical or series of publications containing physical oceanographical papers and that authors see to it that copies of papers which are not published in any such periodical or series are sent to the above-mentioned abstracting journals, accompanied always by an author's abstract.

2. The Committee suggests that the above recommendation be communicated to the General Secretary of the Union, asking that the steps taken by AIOP for obtaining an adequate abstracting service be made known to the other Associations in case they would like to take comparable measures should the matter not already have been attended to.

Because of the overlapping interests of certain Associations it is suggested that the question of a common abstracting organ for the IGGU may be considered before the next Assembly and reported upon at that Assembly.

b. Classification.

1. The Committee recommends that it be reappointed for a 3 years period with the proviso that its task be limited to prepare for presentation to the next meeting of the AIOP a generally acceptable classification scheme of physical oceanographic literature within the framework of the Universal Decimal Classification.

C 7

REPORT OF COMMITTEE ON THE GEOPHYSICAL YEAR 1957—58

By
G. E. R. DEACON
Secretary

The Committe makes the following recommendations for the International Geophysical Year 1957—58.

1. Observations of the existence, generation and propagation of long-period, non-tidal, oscillations of sea level: — (a) seismic and storm surges (b) longer changes in level such as might be caused by seasonal changes in temperature or wind. The Committee recommends acceptance of the U.S.A. plan that long-wave recorders and tide-gauges be installed on as many islands as possible, as well as on continental coasts, a reasonable proportion of the measurements should be made in oceans with good meteorological cover, and some in regions where there are seasonal changes in the prevailing wind. The Committee also asks for regular bathythermograph measurements of the upper 200 m of water near the recording station as well as the usual meteorological data.

2. Studies of the water circulation in the equatorial region along two north-south lines and a number of shorter lines, all sited where ships and scientists can most readily be found to make and repeat observations. The Committee recommends that a reasonable proportion of the effort should be devoted to the measurement of actual water velocities, and to the heat exchange between the sea and air, as well as the usual measurements of temperature, salinity etc.

The chief aim of this and the following recommendation is to improve our understanding of oceanic circulation, and the Committee recommends that countries which have no hope of putting forward adequate facilities to assist materially in the main plan should themselves, and pr. eferably in collaboration with their neighbours, study the water circulation in seas where the results will have a bearing on the main programme, or where the work will

benefit from being done at the same time as the main programme. The western Mediterranean Sea and the Southern Ocean are examples of where such work might be done.

3. Studies of the processes involved in the shifting of the boundary region between temperate and arctic waters, and in the warming of the Arctic. The Committee considers that much of this can be done by suitable arrangement of existing effort. Two international authorities, the International Council for the Exploration of the Sea, and the International Council for the North Atlantic Fisheries have special interests in the North Atlantic Ocean and the Committee strongly recommends that these authorities should be approached as soon as possible, and urged to intensify their work on oceanic circulation during the International Geophysical Year, and to plan the visits of research vessels to these regions so that the observations are more synoptic and so that the problems of water movements and structure of water masses near the Polar front can be fruitfully worked out on an international basis.

4. Although the Committee realizes the usefulness of studying the CO_2 balance between the atmosphere and oceans, and the amount and composition of dust reaching the ocean surface, it feels that oceanographers in general can do no more than offer such facilities as their other work will allow to these studies. It is not thought that their other commitments will allow them to provide apparatus or to analyse the results. The Committee feels that these questions should be discussed with the Association for Meteorology and suggests that the necessary observations might be made in the Weather Ships.

5. In view of the growing use of stationary and towed electrodes for measuring water movements, the Committee feels that a better understanding should be obtained by the electric «earth» currents flowing in the sea, and that the possibility of measuring such currents with ocean cables and relating the results to measurements made by the Association of Meteorology, and of Terrestrial Magnetism and Electricity should be discussed with representatives of these Associations.

6. The Committee recommends that the Ocean Weather Ships be asked to assist the studies of oceanic circulation by making regular bathythermograph observations.

7. The Committee recommends that oceanographers setting up

recording stations on islands and other out of the way places, should give what help they can to the Association of Seismology in setting up seismic recording apparatus.

8. Finally the Committee wishes to emphasise the need for adequate arrangements to ensure prompt analysis and publication of the material which is collected.

C 8

REPORT OF COMMITTEE ON STORM SURGES

By

A. T. DOODSON

Chairman

The Committee agreed that a publication of data of storm surges experienced in past years in a small number of selected areas, and kept up to date by periodical supplements, would be of great value in research on the subject.

The data would comprise:

a. the original tide-gauge observations.

b. a numerical representation of the predicted or synthesised tide.

c. the difference, which would be a first approximation to the true surge.

d. synoptic charts of the meteorological situation.

The object is to give data which have not been subjected to any unknown processes of reduction; hence the necessity of stating what has been taken as the predicted tide, for in future years a better representation of tide may be available. Similarly (c) expresses only a first approximation to the surge and corrections for interaction of tide and surge would not be incorporated.

For each storm surge about 8 or 10 pp. of tables or diagrams would be required, and as the number of storm surges worthy of record is not great the size of publication would not be great nor would its cost.

The storm surges chosen would need to be outstanding examples.

It is deemed to be unpracticable at present to include data for straight coasts, and it is suggested that a small number of regions be chosen which could be regarded as «natural laboratories». These regions would not be chosen on grounds of national

interest but of suitability for research. Suitable areas would be

a. The North Sea, Baltic, Irish Sea, English Channel, and the Bay of Biscay, considered as a single area, or as separate units.
b. The Gulf of Mexico.
c. The St. Lawrence.

It is essential to choose regions which are well served with tide gauges.

It is proposed that an editorial committee be appointed, whose secretary will receive all data and who will supervise the production of the volume. The number on the committee should not exceed 4, but it will be expected that from countries near the selected regions reporters will be chosen to collect data within their country.

C 9

REPORT OF COMMITTEE ON CURRENT MEASUREMENTS

By
W. S. VON ARX
Secretary

In a meeting on 22nd September, the new-established Committee discussed its task.

It was recommended that the Chairman should revise his review of «Principles of Measuring Currents» and prepare it for printing as a Scientific Publication.

The terms of reference of the Committee were recommended as printed on p. 13.

It was understood that the efforts of the Committee should be devoted to the period from 1933 to the present, namely, since the publication of Thorade's report. The mode of assembling information should follow approximately the following schedule:

1. To compile a bibliography of published descriptions of instruments and also to describe them briefly and to list researches in which these instruments have been used;
2. To categorize insofar as possible instruments particularly well adapted to measurements in the following oceanic regions: (a) surface, (b) middle depths, (c) bottom, (d) turbidity or density currents, (e) estuaries and inshore waters, (f) in laboratory models;
3. To note future possibilities suggested in the literature and untried schemes which seem to offer promise.

While it is desirable that the literature in all languages be searched, Dr. Romanovsky has kindly offered to bear the major burden of reviewing Russian reports.

In addition to the general descriptions of instruments and methods it seemed desirable that the Committee categorize the merits of various types of directional vanes, propeller designs, sensing systems and recording or indicating apparatus, both generally, as Dr. Böhnecke has done in his symposium paper, and perhaps also specifically in the description of each instrument.

C 10

REPORT OF JOINT COMMISSION ON OCEANOGRAPHY

By

C. D. OVEY

Provisional Secretary

The main features of the work of the Commission are here outlined. The first meeting of the Commission, held in Monaco at the Oceanographical Museum and at the International Hydrographic Bureau in September 1952, passed a number of resolutions which have born fruit. Firstly, as an outcome of their work, a journal for deep-sea research, entitled *Deep-Sea Research*, has been established and is published by Pergamon Press Limited, London. The first issue appeared in October 1953 and it now seems that there is a steady increase both in the number of contributors and in circulation. Secondly, a symposium was arranged and held at Liverpool in September 1953 at which there were thirtheen principle speakers covering a wide range of subjects, both physical and biological, concerning the deep-sea floor. This was well attended, provoking lively discussion, and some of the contributions have been published in *Deep-sea Research*. Thirdly, a grant-in-aid has, through the International Council of Scientific Unions, been made by UNESCO to the International Hydrographic Bureau in order to speed the production of the General Bathymetric Chart of the Oceans. This is of particular value for users in the scientific field and for those organizing deep-sea expeditions.

In view of the fact that under existing statutes the J. C. O. can only exist in its present from for approximately three more years, it is considered desirable to lay plans for the continuance of its work after that time by some other suitable body. It is accordingly recommended that the J. C. O. be reconstituted to further the work which it is already doing.

In the remaining three years consideration will be given to what form the future body should take in order to avoid overlapping.

[Immediately before the printing of this report the Secretary was informed that the Executive Board of the International Council of Scientific Unions (ICSU) has recommended the abolishment of the Joint Commission on Oceanography and the appointment of a small Committee to propose a plan of action for deep sea research].

General Reports

E 1

BRITISH NATIONAL REPORT OF PHYSICAL OCEANOGRAPHY 1951 TO 1954

Oceanographic surveys.

Fishery research vessels from Lowestoft have made surveys in the southern North Sea and in the Norwegian and Barents Seas. Vaux (1953) has described conditions in the North Sea during the cold winter of 1946 to 1947, and Lee (1952) has summarized the arctic results in relation to the northern fisheries. Scottish research ships from Aberdeen have made surveys from the northern North Sea to Faroe and Iceland and kept a close watch on the incursion of Atlantic water into the North Sea; Tait (1954) has described large fluctuations, and shown that there has been a tendency since 1946 for the current to be much stronger in autumn than in spring. He has used Ekman current meters near the bottom, and registered no current on the sill of the Wyville Thomson ridge. Bowden (1954) has written a full account of the oceanography of the Irish Sea. The National Institute of Oceanography (1953) has published a list of observations taken in the Benguela Current and Indian Ocean, and Currie (1953) has written a note on the upwelling in the Benguela Current. The British Museum (Natural History) arranged an expedition to the Gulf of Aqaba, and Deacon (1952a) has given a short account of the temperature and salinity distribution.

The National Institute of Oceanography completed another survey of the Southern Ocean in December 1951 (Herdman, 1952), and H. M. S. CHALLENGER an extended research cruise in the Pacific Ocean (Ritchie, 1952). Commander Lumby has been preparing

monthly charts of the temperature and salinity of the waters in the eastern North Atlantic Ocean. Current data for these charts were supplied by the National Institute of Oceanography. The task of compiling the charts has now been transferred to the International Council for the Exploration of the Sea.

Continuous surveys of the temperature and salinity of the surface waters of the North Sea, English Channel end Irish Sea have been kept up by the Ministry of Agriculture and Fisheries, Lowestoft, the Marine Biological Association, Plymouth, and the University of Liverpool.

Herdman (1953) has given an account of the distribution of Antarctic pack-ice in winter.

Water Circulation in the Oceans.

T. V. Davies (1953) has published theoretical work on the movements in a rotating viscous fluid heated from below, and has since been developing his technique to a stage in which it can be used for realistic studies of the thermodynamic circulation of the oceans. Proudman, in his book *Dynamical Oceanography* (1953), has shown that the frictional force of the wind on the Southern Ocean need not all be balanced by bottom and lateral friction; it is possible for increments of easterly momentum, due to the wind, to be convected out of the region by the northward movement of water. Eady (1951) has argued that the deep-water ciculation in the oceans may be maintained by the winds, and suggests that the meridional movements of water in deep layers may prove to be due not to convective processes in which the water sinks to a level appropriate to its density and then spreads out, but to the action of the wind in the presence of longitudinal land barriers and a tendency for the water to take the path of least resistance. He has instanced the greater activity of the water circulation in the Atlantic Ocean which is long and relatively narrow, compared with that in the Pacific Ocean in which the longitudinal barriers are much further apart.

Cooper (1952) has continued to seek the underlying causes of the long-term changes in abundance of nutrients and nature of macroplankton in the English Channel, and has called attention to processes that are likely to influence the exchange between the

English Channel and the deeper water off the shelf, and between the deep and shallow waters near the continental slope.

Wind and Currents.

Carruthers, Lawford and Veley (1951a, b, c) have interpreted continuous current measurements from light vessels in terms of the local winds. Bowden has used continuous measurements of the flow of water through the Strait of Dover made by the electromagnetic method using a submarine cable across the Strait. Although there is a fairly steady relation between the local wind and current, there are times when the current depends mainly on a difference in water level between the two ends of the Strait caused by distant weather conditions. Bowden (1953a) has written a theoretical paper on the effect of wind on a channel in the presence of tidal streams, and has described (1953b) the measurement of wind-drift currents in open ocean using the method of towed electrodes.

The National Institue of Oceanography has collaborated with the Department of Meteorology, Imperial College, London, in measurements of wind drag over the surface of the sea in the westerlies and trade winds. (Sheppard, Charnock and Francis 1952).

Storm Surges.

Rossiter (Liverpool Observatory and Tidal Institute, 1953) and Farquharson (Hydrographic Dept., Admirality, 1954) have published detailed accounts of the disastrous storm surge of 31 January to 1 February 1953. H. M. Government has set up a warning system, and has accepted the recommendation that existing tide gauges should be improved and a number of supplementary gauges installed. The Departmental Committee on Coastal Flooding in its First Report recommended research on the nature, extent and rate of response of the sea surface to winds of different intensity, duration and fetch, the modification of long waves and surges in shallow water, study of the free and forced oscillations possible in the North Sea, improvement of formulae for prediction, and extension of practical studies to places other than Southend. Goldsbrough (1952) and Proudman (1954) have extended the dynamical theory of storm surges.

Tides and Internal Waves.

Doodson and Corkan (1952) have made a theoretical examination of tides in a rotating square sea using reiteration methods. One of the important results was the tendency of tidal oscillations which rotate round the sea in the opposite sense to that of the bodily rotation of the sea to be annulled or reversed. Doodson, Rossiter and Corkan (1954) have applied the method to the Irish Sea. Fairbairn is calculating the semi-diurnal tides along the Equator in the Indian Ocean from coastal observations. Bowden and Fairbairn (1952), using observations taken by the University of Liverpool, have calculated tidal friction from velocity/depth profiles and horizontal pressure gradients using a five-mile base-line in Red Wharf Bay off Anglesey. Their values are in close agreement with earlier estimates.

Mortimer has made a study of internal waves in Lake Windermere (1952) based on frequent measurements of temperature profiles over five days. He recognizes two kinds of movement, motion under wind stress which leads to a fairly steady state with the isotherms tilted to one end of the lake, and internal wave motion which develops mainly after the wind has dropped. In the same paper M. S. Longuet-Higgins worked out a three-layers theory which was found to give better agreement with the observations than Wedderburn's two-layer theory.

The Liverpool Tidal Institute and the Anglo-Iranian Oil Company have been collaborating in the study of load tilt and earth tides. The work has been described by Corkan (1953) and Tomaschek (1952).

Waves.

Tucker (1952a) has described a shipborne wave recorder made by the Institute of Oceanography. It has been used more or less continuously in the north-east Atlantic Ocean since early 1952, first by R. R. S. DISCOVERY II, but mainly by the Ocean Weather Ship WEATHER EXPLORER Waves 40 feet high have been recorded on a number of occasions, and the highest wave so far recorded, on 16 November 1953, is 51 feet.

Darbyshire (1952) has described an investigation of the height and length of ocean waves and swell in relation to the strength,

extent and duration of the wind in the generating area and the subsequent travel of the swell through calm and disturbed water. The investigation was based mainly on records of waves made on the north coast of Cornwall, in the Irish Sea and in Lough Neagh, but the conclusions appear to be satisfactory when applied to the new deep-water observations.

Longuet-Higgins (1953a) has worked out a theory for the mass transport in waves which accounts quantitatively for the forward velocities near the bottom which were observed by Bagnold, and shows what further measurements are most desirable. Davies (1951, 1952) has also contributed to the problem of finite-amplitude waves and applied his method to the solution of the solitary-wave problem. Longuet-Higgins (1952) has also derived the statistical distribution of wave-heights theoretically on the assumption that the wave spectrum contains a narrow band of frequencies and the phases of the component wave trains are randomly distributed. The results agree closely with measurements of 20-minute wave records.

Ursell (1952a) has considered discrete and continuous spectra in the theory of waves and has emphasized his early (1946) discovery that waves leaving the storm area behave as a continuous spectrum, each element of which travels independently towards a distant coast with (under ideal conditions) the classical group velocity appropriate to its period. Deacon (1952b) and Tucker (1952b) have pointed out that Fourier analysis has proved itself the most useful method of analysing wave records. A power spectrum obtained by incorporating a circuit which squares and smooths the output of the filter can be used for study of the energy distribution. They point out that wave records look like mixtures of sine waves and can be reasonably treated as such: an autocorrelogram is an unnecessary step in the analysis of such records.

Francis (1951) has studied wind-driven waves in a model tank. The measurements suggest that the drag coefficient increases linearly with velocity so that the drag is proportional to the cube of the wind speed. He concludes that the drag is due more to small roughnesses or short waves than to the principal wave forms, and is now maintaining that the energy dissipated by turbulence is an important factor in wave generation and decay.

Martin, Moyce, Penney, Price and Thornhill (1952) have de-

scribed theoretical work on wave diffraction and standing waves, and theoretical and experimental work on the collapse of a vertical column of a perfect liquid surrounded by a lighter fluid. Sir Geoffrey Taylor (1953) has made an experimental study of standing waves of large amplitude in water. He found a decrease in frequency with increase in amplitude and showed that the angle at the crest was 90 degrees when a critical amplitude was reached. Ursell (1952b) has verified the existence of edge-waves by model experiments and his work may help to explain certain beach phenomena. He has also (1953a) studied the mass transport in surface waves, considered the applicability of the linearized theory of surface waves to practical conditions and dealt with the solitary wave and with waves breaking on a beach. He has given a theoretical treatment of the surface waves produced by an oscillating immersed body (1953b, 1954). Burns (1953) has considered waves on a stream in which the velocity is greater at the surface than at the bottom; his results are mainly applicable to very long waves. In the general case he uses an approximate, linearized, theory which indicates that the velocity of the waves relative to the mean velocity of the water is greater in a stream than in still water. Hunt (1953) has pointed out some significant errors in Struik's paper on travelling waves.

Waves and Microseisms.

Darbyshire (1954) has shown that the bearing of a source of microseismic oscillations can be deduced from records of the three components at Kew. He assumes that the horizontal components consist of both Love waves and Rayleigh waves and that the vertical component consists of Rayleigh waves only. The proportion of Rayleigh waves in each horizontal component was found by the maximum correlation that could be obtained between the horizontal and vertical records as the phase of one is adjusted relative to the other. There are some uncertainties due to fortuitous correlation and the presence of a spectrum of waves, but the ratio of the correlation coefficients gave the correct angle and the phase difference at maximum correlation gave the quadrant of approach. Further evidence was obtained in support of the wave-interference theory. Cooper and Longuet-Higgins (1951) made an experimental study of the pressure variations below standing waves, which supports the wave-interference theory.

Light Penetration.

Atkins and Poole (1952) have published the results of their experimental study of the scattering of light by natural waters. The amount of back scattering in sea water was a small fraction of the total, most of the scattering being found within 25 degrees of the original direction. They have since worked on the angular scattering of blue, green and red light by sea-water (1954).

Herdman (1953b) has given evidence of the association of acoustic scattering with density layers.

Vevers (1951, 1952) has described an underwater camera to take 40 to 50 successive exposures, with a field of 1 sq.m at depths down to 80 m.

The Ocean Floor.

Bullard (1954) has measured the temperature gradient and thermal conductivity in the sediments at five stations in the North Atlantic Ocean. The mean heat flow and conductivity were found to be 0.98×10^{-6} cal/cm^2 and 25×10^{-4} cal/cm/°C/sec. The mean heat flow is only 20 per cent less than that obtained on land.

Carruthers and Lawford (1952) have reported on the deepest oceanic sounding made by H. M. S. CHALLENGER in the Mariana Trench. Gaskell and Swallow (1953a) have described seismic experiments on two Pacific atolls, and (1953b) seismic work in the Indian Ocean and Mediterranean Sea, made during the same voyage. Hill (1952a, b) has reported the results of seismic refraction measurements in the eastern North Atlantic Ocean, and Hill and King (1953) have described similar investigations and their geological meaning in the English Channel.

Wiseman and Hendey (1953), examining diatoms from the bottom of the Mariana Trench, found evidence of the solution of silica.

Chemistry of Sea Water.

Atkins (1953a) has described the changes in dissolved compounds of phosphorus and silicon at a position near Plymouth in 1948, and Armstrong (1954) during the years 1950 to 1953, whilst Cooper (1952c) has reviewed the cycle of silicon in the deep sea. At the same place Atkins (1953b) has shown that during the year the content of copper in sea water undergoes a cycle — resembling

that for phosphate and nitrate. Atkins and Jenkins (1953) have also used changes in the amount of chlorophyll to determine the mass of phytoplankton throughout the year, and have identified the organisms concerned. Biological differences between natural waters have been found by Wilson (1951) and Wilson and Armstrong (1952). This work may indicate means of biological assay in the sea of chemical agents which have defied chemical analysis. Cooper (1951) has produced evidence for the enrichment of the Celtic Sea with phosphate due to regeneration of bottom muds.

Smales (1951), using radioactivation methods, found the strontium content of North Sea and deep Atlantic water to be near to 10 mg/l, whilst Smales and Pate (1952) found that the arsenic content of English Channel waters lay between 2 and 5μg/l, a result confirmed by Harvey by a chemical method. This is much lower than the content found in the English Channel thirty years ago by other methods.

Black (Institute of Seaweed Research) and Mitchell (Macauley Institute of Soil Research) (1952) have reported on the concentrations of nickel, molybdenum, zinc, vanadium, titanium, chromium, silver and strontium in sea water.

Riley (1953) has described the spectrophotometric determination of ammonia in sea water, and Bather and Riley (1953) an accurate potentiometric determination of salinity developed at Liverpool University. R. A. Cox (National Institute of Oceanography 1954) has described a method of measuring salinity using a variable density float.

Johnston (1952), at Aberdeen, has described the winter and summer distributions of free phosphate and dissolved oxygen in the Faroe-Shetland Channel.

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E 2

A REVIEW OF CANADIAN OCEANOGRAPHY

By

H. B. HACHEY

Canadian Joint Committee on Oceanography

Canada with the sea on three coasts is directly concerned with three oceans, and attention is given to the many oceanographical problems related to navigation, fisheries, defence and other items of national import. While many of these problems are concerned with a small area, a particular local fishery, or a specific limited defence item, others may be of greater moment involving a fishery of international interest, a meteorological problem involving the circulation of an ocean, or a navigational or tidal problem involving a whole coast. In any event, a knowledge of the oceans from a physical, chemical, biological, or geological viewpoint, is involved. Oceanography, as a practical subject in Canada, thus finds its function in a study of the sea by individual government agencies, and by several organizations, working on a co-operative basis.

The particular advantage of co-operative research in oceanography comes from the pooling of resources in personnel, ships and equipment which, at the best, are very limited. It also brings together researchers of the varied disciplines so necessary to the proper prosecution of oceanographic research. It was with these points in mind that the Canadian Joint Committee was formed in 1946, involving the Fisheries Research Board, the Royal Canadian Navy, the National Research Council, and the Hydrographic Service. The chief function of this committee, is to further oceanographic research in Canada, and to direct, through the Chief Oceanographer, the work of the Atlantic and Pacific Oceanographic Groups located

respectively at the Atlantic Biological Station at St. Andrews, N. B., and the Pacific Biological Station at Nanaimo, B. C.

The operating budget of the Oceanographic Groups for salaries and operational expenses are provided chiefly through the Fisheries Research Board, with a token grant from the National Research Council. Laboratory facilities for the Oceanographic Group on each coast are provided by the Fisheries Research Board, while suitable oceanographic research ships are operated and maintained by the Royal Canadian Navy. These ships are fitted with suitable laboratory facilities and all the modern equipment required for physico-chemical oceanography.

On the Atlantic Coast attention is given to the interesting problems arising in the area of confluence of the Gulf Stream and Labrador current. A particular fundamental problem is concerned with the formation and distribution of „slope water". On the practical side the study of the distribution of various waters of contrasting characteristics has its application in many problems of fisheries and defence.

On the Pacific Coast, the vagaries of the shoreward transport of the waters of the North Pacific Current are studied, as one of the most important factors in determining the characteristics of the coastal waters of British Columbia. The many island groups extending along the British Columbia Coast, and many coastal indentations forming fjord-like inlets constitute an area unique in opportunities for oceanographic studies of fundamental interest and for application to problems of the fisheries.

In the Arctic, while the investigations are as yet of the nature of reconnaissance, a realistic program is now underway both in the eastern and western Arctic.

E 3

PHYSIKALISCHE OZEANOGRAPHIE AM DEUTSCHEN HYDROGRAPHISCHEN INSTITUT 1951—1954

Von

WALTER HANSEN

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1. *Morphologie und Geologie.*

Die Tiefenverteilung und die Morphologie werden für Teile des Atlantischen Ozeans sowie in Nord- und Ostsee behandelt, die Ergebnisse sollen in Atlanten, in Wandkarten und in einem Relief dargestellt werden. Über die grösste heute bekannte Tiefe des Weltmeeres berichtet Stocks (1). Die verwendung von Echoloten zur Ermittlung der Bodengestalt behandelt Schüler (2), (3), (4), (5). Bodenproben und Echogramme werden gleichfalls zu diesem Zwecke verwendet (6). Stocks und Schüler stellen Betrachtungen an über die Ermittlung der Mächtigkeiten von Schlickschichten mit Hilfe des Echolotes (7), (8).

Pratje setzt die Endmoränenzüge in der Nordsee in Beziehung zu den vom Lande her bekannten Vereisungsstadien (9). Über den tieferen Untergrund im Nordseebereich hat Jatke gearbeitet (10). Geologische Probleme der Tiefsee (11) und spezieller Gebiete wie der Norwegischen Rinne (12) und Helgoland (13) hat Pratje behandelt und Erfahrungen bei der Gewinnung von Grundproben mitgeteilt (14), (15).

Ein Atlas mit Angaben über die Bodenbeschaffenheit in der südlichen Nordsee, der auch Tiefenkarten enthält, ist in Arbeit.

2. *Meeresströmungen und Oberflächengestalt des Meeres.*
(Triftstrom, Stau, Massenaufbau)

Die Untersuchungen über den Einfluss des Windes auf die Strömungen und den Stau wurden fortgesetzt (1) und Methoden zur numerischen Ermittlung der Bewegungen entwickelt und auf ihre praktische Anwendbarkeit geprüft (2), (3). Arbeiten über den windbedingten Stau in ein- und zweidimensional ausgedehnten Randmeeren (Nordsee) sind im Gange, der Fall eines zeitveränderlichen Windfeldes ist in die Betrachtungen eingeschlossen. Über einen Teil dieser Ergebnisse sowie über neuere Beobachtungen der Amerikaner am Golfstrom berichtet Hansen (4).

Bemerkenswert ist, dass die verwendeten Metoden, die wesentlich den Übergang von den hydrodynamischen Differentialgleichungen zu den zugehörigen Differenzengleichungen benutzen, wobei die Reibung eine entscheidende Rolle spielt, sowohl zur Ermittlung stationärer als auch instationärer Bewegungsvorgänge geeignet sind.

Die aus den neueren amerikanischen Beobachtungen (Cabot) gewonnenen Kenntnisse über die Bänderung und die scharfe seitliche Begrenzung des Golfstromes haben Anlass zu einer Betrachtung gegeben, in der die Vorgänge in Parallele gesetzt werden zu speziellen Lösungen der hydrodynamischen Gleichungen (5).

Die Untersuchung des Zusammenhanges zwischen beobachtetem Windstau in Cuxhaven und den entsprechenden Werten in ausgewählten Orten der deutschen Nordseeküste hat einen Einblick in die regionale Verteilung der Windstauunterschiede und deren Abhängigkeit von Windrichtung, Tiefenverteilung und Küstengestalt gegeben (6), (7). Hochseepegelbeobachtungen gaben die Möglichkeit, in der inneren Deutschen Bucht Flächen gleichen Windstaus für dieses Gebiet zu entwerfen (8). Über die historische Entwicklung, die Organisation und die Vorhersageverfahren des Windstau- und Sturmflutwarndienstes wird in Kürze eine Veröffentlichung erscheinen (9).

Ein Abriss der dynamischen Ozeanographie, der vornehmlich Tabellen und Darstellungen enthält, wurde im Landolt-Börnstein gegeben (10).

Salzgehalt, Temperatur und deren zeitliche und räumliche Änderung in den Ozeanen und in den Randmeeren wurden von Diet-

rich behandelt (11), (12), (13), der auch die Oberflächenströmungen im Kattegat, im Sund und in der Beltsee bearbeitet hat (14). In einer Gemeinschaftsarbeit sind die Windverhältnisse über der Nordsee und den britischen Gewässern dargestellt worden (15), (16).

3. *Periodische Bewegungen.*

Gezeiten und Oberflächenwellen.

Nach Abschluss der methodischen Untersuchungen zur Ermittlung der Gezeiten in Gewässern grösserer Tiefe (Randwertverfahren) wurden entsprechende Untersuchungen für Seichtwassergezeiten (Flussgezeiten) durchgeführt. Hansen betrachtet die Genauigkeit der erzielten Ergebnisse an Hand ausgewählter Beispiele aus der Nordsee und von der Elbe (1) und behandelt den Einfluss der Tiefenverteilung auf die Gezeiten (2). Aus Strombeobachtungen in der Nordsee wurden die Ellipsenelemente und die Restströme bestimmt. Die Ergebnisse sind bei der Bearbeitung der Karten des Gezeitenstromatlas der Nordsee verwendet worden und werden bei Untersuchungen über den Zusammenhang zwischen Strom, Salzgehalt. Temeratur, Trübung und Zinkstoff-führung augewertet (3). Joseph benutzt die Beobachtungen zu Betrachtungen über die Beziehungen zum Austausch (4).

Für das Tabellen- und Tafelwerk «Landolt-Börnstein» wurden die Abschnitte Gezeitenkräfte (5) und Gezeiten des Meeres I (6) und II (7) bearbeitet.

Nach eingehenden Vorarbeiten wurde ein neues Verfahren zur Berechnung der Gezeitentafeln für die deutschen Gewässer entwickelt, das auf demselben Prinzip beruht wie die harmonische Analyse, jedoch nicht die Darstellung der Gezeitenkurve in ihrem vollständigen zeitlichen Verlauf anstrebt, sondern die Eintrittszeiten und Höhen der Extrema (oder zeitlich gleichabständige Punkte der Kurve) unmittelbar liefert, ähnlich wie die nonharmonischen Methoden. Bei Seichtwassergezeiten ergeben sich so wesentlich rationellere Reihenentwicklungen. Die hierzu erforderlichen Analysen 19-jähriger Beobachtungen werden als strenge Ausgleichungen nach der Methode der kleinsten Quadrate durchgeführt, ebenso wie die Vorausberechnungen mit Hilfe von Lochkartenmaschinen.

Über die Ergebnisse von Messungen der Oberflächenwellen berichtet Schumacher (8).

4. *Ozeanographische Beobachtungen und Instrumente.*

Die Beobachtungen auf den deutschen Feuerschiffen in Nord- und Ostsee wurden fortgeführt (1). Mit dem Vermessungs- und Forschungsschiff «Gauss» wurden 1950, 1952 und 1953 hydrographische Beobachtungen an der Sprungschicht in der Nordsee ausgeführt, die durch die sommerliche Erwärmung bedingt ist. In den Jahren 1951, 1952 und 1953 wurde auf Reisen des Vermessungs- und Forschungsshiffes «Gauss» die Ausbreitung und Vermischung der Wassermassen in der südlichen Nordsee untersucht. Neben Salzgehalts- und Temperaturmessungen wurden die Ströme, die Trübung und die Verteilung chemischer Elemente und Verbindungen gemessen.

1951 wurden Schaufelradstrommessungen und Hochseepegelbeobachtungen mit dem Tonnenleger «Kapitän Meier», den das Wasser- und Schiffahrtsamt Tönning zur Verfügung stellte, in der inneren Deutschen Bucht ausgeführt.

Geräte zur gleichzeitigen Registrierung der Extinktion, der Temperatur und des Temperaturgradienten wurden entwickelt und erprobt. Ausserdem läuft eine Entwicklung von Geräten zur Messung der hydrographischen Elemente vom fahrenden Schiff aus.

5. *Physik und Chemie des Meeres.*

Die Abschnitte Chemie des Meeres, Meeresoptik und Physikalische Eigenschaften des Meerwassers sind für den Landolt-Börnstein, Zahlenwerte und Funktionen, Band III, Astronomie und Geophysik, bearbeitet worden (1), (2), (3).

Die Feinstruktur der Temperatur im Meere (4) sowie die Trübungsverhältnisse und der Chemismus der Wasserkörper in der südlichen Nordsee (5), (6) sind eingehender behandelt worden. Ausserdem gibt Kalle Hinweise, die die Chlortitration (7), die Chlorophyllbestimmung (8) und die Auswertung von Kippthermometermessungen betreffen (9).

6. *Meereis.*

Zur Vervollkommnung der wissenschaftlichen Grundlagen des praktischen Eisdienstes wurden die Eisverhältnisse der Deutschen

Bucht und der westlichen Ostsee eingehend bearbeitet, und die textliche und kartenmässige Darstellung der Ergebnisse in Angriff genommen. Ausserdem wurde der Zusammenhang zwischen den Grosswetterlagen und der Eisbildung, und die Beziehung zwischen den Wassertemperaturen und dem ersten Auftreten des Eises untersucht. Über die Eisverhältnisse an den deutschen Küsten hat Nusser laufend berichtet (1), (2).

Folgenden Herren dankt der Verfasser für Bereitstellung von Unterlagen bei der Abfassung des vorstehenden Berichtes:

Dietrich, Horn, Jarke, Joseph, Kalle, Model, Neumann, Nusser, Schumacher, Sendner, Stocks.

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E 4

RAPORT SOBRE LOS TRABAJOS REALIZADOS EN ESPANA SOBRE OCEANOGRAFIA FISICA DESDE EL ANO 1951

Instituto Español de Oceanografia

Campañas oceanografiacas.

El año 1951 del 9 al 30 de Enero se exploró la parte oriental del mar de Alborán siguiendo tres perfiles transversales de Norte a Sur en los meridianos de 3°00'W, 2°30'W y 2°00'W. Se realizaron 29 estaciones y se determinó la salinidad, la temperatura, el contenido de oxigeno y la naturaleza del fondo.

Del 21 de Junio al 17 de Julio de 1951, se realizó una estación fija en torno a los 5°20'W y 36°00'N, en la que se determinaron por espacio de 14 horas temperaturas y salinidades cada hora.

Se hicieron los perfiles transversales de Norte a Sur en los meridianos 5°10'W, 4°30'W, 4°00'W, 3°30'W y 3°00'W. Se tomaron muestras en 69 estaciones, determinándose la temperatura, salinidad, contenido en oxigeno y naturaleza del fondo.

Del 6 de Marzo al 10 de Abril del mismo año se hizo una campaña en la costa norte de Marruecos Español, zona del Muluya, tomándose temperaturas, salinidades y planton.

Del 6 de Agosto al 5 de Septiembre se hizo un crucero a lo largo de la costa sudatlántica-atlántica y cantàbrica de la peninsula Ibérica, realizandose 51 estaciones en las que se determinaron temperaturas, salinidad, oxigeno y fosfatos.

En el año 1952 del 7 de Febrero al 28 de Marzo se hicieron en el mar de Alboran y parte oriental del estrecho de Gibraltar 71 estaciones, determinándose la temperatura, la salinidad y la naturaleza del fondo.

Del 2 de Agosto al 2 de Octubre se hizo un crucero a lo largo

de la costa sudatlántica-atlántica y cantábrica de la peninsula Ibérica, comprendiendose 75 estaciones en las que se determinaron temperatura, salinidad, contenido de oxigeno, fosfatos y naturaleza del fondo.

Del 13 de Diciembre al 22 de Diciembre se realizaron 22 perfiles batimétricos normales a la costa del Sahara Español. Se determinó la profundidad con eco-sonda y tomaron muestras del fondo.

En el año 1953 del 29 de Enero al 16 de Febrero se hicieron 35 estaciones a lo largo de las costas del Marruecos Español determinándose temperaturas y naturaleza del fondo.

Del 24 de Julio al 1 de Octubre se hicieron 77 estaciones a lo largo de la costa sudatlántica, atlántica y cantábrica de la peninsula Iberica. En ellas se determinaron temperaturas, salinidades, oxígeno, fosfatos y naturaleza del fondo.

De Agosto a Septiembre se midieron las temperaturas, salinidades y contenido en oxígeno en una situación anclada y diferentes puntos del mar Menor (Murcia).

En el año 1954 se realizó una campaña en el Mediterraneo Balear desde el 15 de Enero hasta el 8 de Marzo. Durante ella se hicieron 98 estaciones en las que se determinaron temperaturas, salinidades, contenido en oxigeno, fosfatos, naturaleza del fondo y planton.

Observacion de temperaturas.

Se determinó casi a diario la temperatura superficial y a 20 m de profundidad en Barcelona, Palma de Mallorca, Málaga Vigo y Santander, empezándose a estudiar las fluctuaciones de sus términos armónicos.

Mareas.

Se atendieron y recogen los datos de los mareógrafos de Pasajes, Santander, Gijón, Vigo, La Coruña, Cadiz, Tarifa, Algeciras, Málaga, Ceuta, Las Palmas, Sta Cruz de la Palma y Arrecife. A base de los datos recogidos se determinaron los nivelos medios mensuales y annuales de todos estos puntos desde la fecha de su instalación hasta el día.

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E 5

OCEANOGRAPHY IN FINLAND

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The Institute of Marine Research (Merentutkimuslaitos/Havsforskningsinstitutet) has continued its regular observations on ice, temperature, salinity and other chemical properties, currents and water level in the coastal region of Finland. A real sea expedition in the Northern Baltic could not be made, but a special research ship is intended to start working in summer 1954.

Among the investigations about the ice may be mentioned, that professor *Risto Jurva* (dead in Dez. 1953) has continued his extended studies on the ice questions in the Baltic. Dr. *Heikki Simojoki* has published a survey on the ice winters 1946—50, and a synopsis on the time for freezing and ice break-up on the Finnish coast, and, moreover, studied the influences of ice jams on river level rising in springtime, and the rhythmic winter temperature variations. Dr. *Erkki Palosuo* has published an investigation on severe ice conditions in the Central Baltic.

Concerning the physical and chemical properties of the sea water professor *Kurt Buch* has accomplished his investigations about their influences on the biological activity in the Archipelago, and started collaboration with institutions in other countries in order to continue his researches of the sea's regulating effect on the increase of carbonic acid in the atmosphere produced by the combustion of fossil carbon. Dr. *Gunnar Granqvist* has started an investigation of temperature and salinity conditions in the Archipelago and published the Finnish regular observations of these elements until 1952 June. Dr. *Folke Koroleff* has studied the determination

of alcalinity by simplified methods, and methodics for determination of trace elements, phosphorus and silicium.

The variations of the water level has been the research field of Dr. *Ilmo Hela*. He has published a study of the land upheaval on the Finnish coast, and the water level observations in 1947 and 1948 and furthermore continued his investigations on the Florida current and related questions. Dr. *Eugenie Lisitzin* has published the Finnish observations on currents and wind during the years 1948—51, finished a contribution to the knowledge of the range of the sea-level variations in the Northern Baltic and a paper on its internal waves, and, moreover, started a research on the sea-level variations in the Monaco area of the Mediterranean.

E 6

NOTE ON RECENT OCEANOGRAPHIC WORK IN INDIA

By

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The oceanographic work carried out in India can be summarised as under:

i) Physical Oceanography studies made by the Indian Navy, the India Meteorological Dept., the Andhra University, at the Central Marine Fisheries Station at Mandapam;
ii) Tidal observations done by the Survey of India;
iii) Marine Biological studies carried out by the Central Marine Fisheries Research Station, Mandapam, Fisheries Departments of certain Maritime States and the Zoology Departments of Universities situated on the sea coast.

1. *Physical Oceanography.*

a) The hydrographic survey of the Indian Navy have been carrying out some oceanographic work with the help of the INS «Investigator». The purchase of a new marine survey vessel and equipping it with laboratory appliances for physical oceanographic studies is under consideration. Assistance has been rendered by the Marine Survey to the Andhra University from September, 1952 for conducting a number of brief oceanographical cruises in the Bay of Bengal along the east coast of India. Facilities were also offered to two scientists of India Meteorological Department in March, 1952 on board the INS «Investigator» for collecting meteorological and oceanographical data in the course of its cruise round

the coast of India. Records of salinity at different depths are re-regularly obtained in Bombay Harbour and occasionally by the ships of the Marine Survey of India. A well equipped physical laboratory has also been established at the Cochin Naval Base and it is proposed to equip this for physical oceanographical work. The Navy has under contemplation systematic work on the analysis of wave and swell experienced in Indian Ocean.

b) The India Meteorological Department have a system of contacting ships plying in Indian seas and collecting reports of meteorological logs giving information about sea water temperature. 140.000 of Hollerith punched cards containing these observations relating to Indian Ocean have so far been prepared. A suitable type of marine bucket designed by the Instrument Division at the Meteorological Office, Poona, to get reliable observations of sea water temperature is now being used by the ships of the Indian Merchant Navy. Ships' meteorological reports previously contained data of sea and swell, and in India and elsewhere such observations were made at coastal observatories also. The Conference of Directors of Meteorological Services, Washington, 1947, decided that (i) sea and swell reports may be given up and (ii) observers at sea or on the coast should report only on the characteristics, viz. period, direction and height of waves they actually see without aiming at any differentiation. Accordingly, ships plying in Indian waters report the observations of waves in the new form since January 15, 1949. Twenty-six Indian Coastal Observatories commenced these visual observations of waves on January 1, 1950. During World War II, visual surf reporting stations were also started along the coast in the Bay of Bengal for a short period.

Surface ocean current data obtained from set and drift observations are occasionally received from observing ships. The volume of data received from ships has increased over recent years and ships are now supplied with special forms for recording the ocean current data. Punched cards obtained from the Dutch Service for the years from 1854 to 1938 also contain set and drift observations made over the Indian Ocean area. Further, from the middle of 1949, observations of the density of the sea water at the surface have been taken almost daily at Colaba and at Alibag (18 miles SSE of Bombay). During monsoon, the density fluctuates widely as has been observed every year. Specific Gravity and sea tem-

perature observations have been arranged for Madras Harbour from 1951.

c) The Andhra University at Waltair (Lat. 170° 42′ 25″ N, 83° 17′ 44″E) in view of its location and availability of adequate harbour facilities and laboratory facilities in the Departments of Physics, Geophysics, Geology and Zoology of the University has become an important centre for oceanographic research in India. Prof. C. Mahadevan, Head of the Department of Geology, Dr. S. R. Savur, Head of the Department of Geophysics and Dr. P. N. Ganapati, Head of the Department of Zoology, have been collaborating in oceanographic work. Physical oceanography is one of the special subjects for the M. Sc. Degree in Geophysics at this University.

The visit of Prof. E. C. LaFond, Head of the Oceanography Branch of the U. S. Navy & Electronics Laboratory, San Diego, California, under the exchange visitors programme of the Fulbright Scheme to this University during 1952—53, resulted in an intensive oceanographic programme for the Bay of Bengal utilizing a minesweeper placed at the disposal of the University by the Ministry of Defence. Much of the special equipment required such as, Bathythermographs, Nansen Bottles, etc. was brought by Prof. LaFond. These were supplemented by other instruments available in the laboratories of the University. During Prof. LaFond's stay, 19 study cruises in the Bay of Bengal and the South Eastern part of the Arabian Sea were carried out. Observations on the Distribution of temperature and salinity at the surface and at various depths, distribution of planktonic organisms and the nature of ocean bottom sediments were made from the samples collected during those cruises, which extended from Madras in the South to the mouth of the Ganges in the North. One cruise was from Visakhapatnam to Cochin round Ceylon. The study of the evolution of the beach configuration with particular reference to tide and seasons was also commenced side by side. It has been noted that the waters of the eastern coast are especially interesting, because the currents are completely reversed when one monsoon is replaced by the other. Owing to the great dilution of the waters of the Bay of Bengal from the enormous rivers, the many long deltaic channels of the Ganges River are ideally suited to the study of estuarine oceanography. The submarine canyon «Swatch of No Ground» probably sets forth turbidity currents and both upwelling and sinking appear

to be present at different seasons. A preliminary report embodying the results of the observations is under publication as a Memoir in Oceanography by the Andhra University. Further work on the geological, geophysical and biological aspects of oceanography on the data collected is now in progress.

d) Physical oceanographical work carried out at present by the Fisheries Station at Mandapam relates only to temperature and salinity observations. Intensive data are kept at Mandapam, Calicut and Bombay and the system of observations is extended by the help of the Naval and Merchant Naval Vessels operating in Indian waters. Water samples collected by the vessels are sent to Mandapam for study along with temperature readings. Recent activities of power fishing vessels from Bombay have opened up new avenues of collection of data.

2. *Tidal Observations.*

The Survey of India (Geodetic Branch) is actively engaged in taking tidal observations with the help of tide gauges installed in various ports. A note on the tidal work carried out is being presented separately by Mr. B. L. Gulatee, Director, Geodetic Branch, Survey of India.

3. *Marine Biological Studies.*

Attempts have been initiated at the Central Marine Fisheries Research Station to obtain a clear picture of oceanographic conditions in relation to fisheries. The results of the previous expeditions on salinity and temperature distribution are being followed up with recent data obtained from fishery and merchant vessels with a view to correlating the data with marine fisheries and fishing. In this expanding programme advantage is being taken of the facilities afforded by deep-sea fishing vessels operating from Bombay and trawling in the newly-discovered fishing grounds to the west of Kathiawar. Another aspect of work which has been started relates to the formation of mud banks, which is a characteristic feature of the waters off Malabar, lower down on the West Coast of India. The possibility of these banks acting as reservoirs of nutrient salts, contribution to the rich fisheries in this area, has been indicated (Seshappa, 1953).

The study of the physico-chemical and biological factors connected with the abundance of Plankton in inshore or neritic waters has been undertaken at the Fisheries Station at Mandapam and its sub-stations. Data have been collected for the years 1948—53 at selected inshore stations (off Calicut, Madras and Mandapam). Considerable variations were observed in the distribution of nutrient salts in the waters of the two coasts and also in the different areas in the same coast (Panikkar & Jayaraman, 1953). Plankton studies in relation to physico-chemical factors have also been carried out at the Zoology Departments of the Andhra and the Madras Universities. The hydrology of Vellar Estuary in S. India in relation to the fauna is being worked out at the Annamalai University.

The purely biological aspects of plankton and diatom production vis-a-vis the fisheries have been studied in detail at the Central Fisheries Station (George 1954; Prasad 1954). The swarming of *Noctiluca* (Bhimachar & George, 1950; Prasad 1953; Prasad & Jayaraman 1954) and of flagellates (Subrahmanyan 1954) has been investigated with reference to the effect on the fisheries of the Indian coastal waters. It is now clear that the periods of diatom intensity in the plankton show considerable variation in the various sectors of the Indian coast. It would appear that the problems of diatom production and the subsequent effects of grazing by the zooplankton are much more complex in warmer waters where the phytoplankton and zooplankton maxima are produced by a large variety of species having varying periods of maxima and minima. It has to be ascertained to what extent the individual maxima of various species are caused by physico-chemical factors or whether they are caused chiefly and only by biological sequences and also whether large-scale planktonic outbursts of flagellates *Noctiluca* and *Trichodesmium* could be taken as indicative of abnormal turbulence raising nutrients available in surface waters far above normal (Panikkar & Jayaraman 1953).

The oceanographic work of the Central Marine Fisheries Station is to be substantially strenghtened in the forthcoming years and it is hoped that the work will receive much impetus with the provision of a Fisheries Research Vessel proposed to be acquired for the Station.

4. *Conclusion.*

In conclusion, it may be stated that the Oceanography Committee functioning under the Central Board of Geophysics from the year 1949 has been considering the problems connected with physical oceanography and marine biology in India. This committee as the co-ordinating body, has been devoting special attention to the question of formulating plans and proposals for establishing a Central Institute of Oceanography at a suitable centre. On the recommendation of this committee, India has joined the National Institute of Oceanography, U. K., on payment of a token subscription.

5. *Acknowledgement.*

In preparing this report, the authors have received valuable notes and contributions from Dr. G. E. Gale (Scientific Adviser, Indian Navy), Dr. L. A. Ramdas & Dr. S.L. Malurkar (India Meteorological Department), Prof. C. Mahadevan and Prof. S. R. Savur (Andhra University).

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E 7

TIDAL WORK IN INDIA

By

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Geodetic & Training Circle, Survey of India.

Tidal operations in India have mainly been, from the very beginning, the responsibility of the Survey of India. The earliest recorded tidal observations were those carried out by James Kyd at the Kidderpore Docks, Hooghly River, during 1806—27. Some observations were subsequently taken at certain other ports by independent observers, and for some places (e.g. Bombay, Calcutta & Madras) even some tide tables appear to have been published; but systematic tidal operations cannot be said to have started in India till about 1879 when the general control and superintendence of tidal observations were entrusted to the Survey of India Department.

2. Systematic tide-gauge observations have been carried out at some time or the other by the Survey of India at about 42 standard ports between Suez and Singapore in the Indian Ocean, the normal length of observations at each port being about 5 years. In the case of certain major ports, observations have continued to be taken from the very beginning (from about 1879) to date, but in a majority of cases the observations were discontinued towards the end of the last century as soon as the necessary data for tidal predictions had become available.

3. For prediction purposes, a new harmonic tide predicting machine manufactured by Lege & Co with 42 components was installed in 1952 at the Geodetic Branch, Survey of India, Dehra Dun. This machine is being used for predictions for all the ports commencing from the year 1956. The older machine of 1879 with 24 components is now completely worn out and is obsolete in many respects.

4. The main publication containing the India Tide Tables is «Tide Tables of the Indian Ocean» — an annual publication which gives predictions for 65 ports in the Indian Ocean, of which 38 ports lying between Suez and Singapore are predicted by the Survey of India, the remaining being obtained on an exchange basis from the Hydrographic Departments of foreign countries. In addition to the above publication, three separate tidal pamphlets are also published every year containing separate tide-tables for Bombay, the Hooghly River (3 ports) and the Rangoon River (2 ports).

5. For most of the ports, the data on which predictions by the Survey of India are based are over 50 years old. In a number of cases, there is evidence of significant changes in the sea-bed, local configuration of the land and in river estuaries, which have an effect of considerable magnitude on the tidal occurrences. It is therefore intended to base future predictions as far as possible on fresh observational data. At present, tide gauges are in operation along the Indian and adjacent coasts at the following ports:

Aden, Kandla, Bombay, Mangalore, Madras, Vizagapatam, three river stations on the Hooghly, Port Blair and Rangoon.

It is proposed to establish before long some more tidal observatories at about seven more ports. In the meantime a touring tidal Detachment, has been visiting certain primary and secondary ports and carrying out hourly observations on tide poles for about a month from which a preliminary assesment of changes in the tidal regime at the various standard ports can be made, and priorities for tide-gauge observations can be as assigned. These observations are also of considerable importance in certain areas of interest where inferred constants only have so far been used for approximate predictions.

6. The methods of tidal analysis and predictions have been overhauled. The older B. A. method of harmonic analysis was discontinued about 34 years ago for all ports at which three years' observations had been analysed, as it was not considered comprehensive enough to yield the desired accuracy. At the moment the Liverpool Institute's method of annual analysis is being followed in respect of any fresh analysis of observational data. Again, in respect of riverain predictions, a combined harmonic and non-harmonic method has hitherto been followed in the Department and this has been found from experience to be far from satisfactory.

The latest Liverpool Institute's method of predictions catering for harmonic shallow water corrections is now being adopted, and a number of riverain ports for which modern data are available have already been analysed by this method. A noteworthy feature of the new tide predicting machine now in use is, that it makes provision for harmonic shallow water constituents for riverain ports.

7. The harmonic analysis of observations having been suspended since 1920, pending the adoption of a more intentive method than the one followed so far, a lot of valuable observational data in the form of tide gauge records for certain ports has accumulated but it has not been possible to use it for any systematic work on M.S.L. valuations or tidal analysis. Some computations of M.S.L. have been carried out in connection with the supply of data to the International Association of Physical Oceanography for printing in their «Publication Scientifique» but some of the values could only be computed from high and low waters instead of rigorously from the hourly heights. It is hoped to take up the work of M.S.L. computations in the near future, after a few more analyses of the various ports are made.

8. Oceanographic activities in India, in so far as off-shore surveys and echo-soundings are concerned, are carried out by the Marine Survey of India. The Survey of India and the Marine Survey Department are in close liaison with each other regarding their coastal programmes and tidal observations.

E 8

PHYSICAL OCEANOGRAPHY IN IRELAND 1951—1953

Department of Agriculture, Fisheries Branch

Sea temperatures taken at lightships are summarised and the data transmitted regularly to the Oceanographical Section of the International Council for the Exploration of the Sea.

E 9

OCEANOGRAPHY IN TEXAS

By

John C. FREEMAN, Jr.

Agricultural and Mechanical College of Texas

In the fall of 1949 a Department of Oceanography was established at Texas A. & M. College in the School of Arts and Sciences. The various departments on the campus realized that there was need for a central agency to teach Oceanography and to undertake studies of the Gulf of Mexico. The department grew rapidly until at present some 100 persons are on the payroll including an academic staff of 15 and a research staff of 19 other scientists.

By the spring of 1952 an undergraduate program in the Meteorology Option was added to train scientists in this field and to cover the applications of weather knowledge to marine problems as well as to agriculture, shipping, engineering, civil and industrial planning, health, travel, recreation and related sciences. Also a basic training curriculum for Air Force Officers was initiated.

The degrees of Master of Science and Doctor of Philisophy are offered in each of the 5 phases of Oceanography, the biological, the chemical, the geological, the physical, and the meteorological.

In addition to the academic program, contract research is conducted through the Texas A. & M. Research Foundation on 20 projects sponsored by various government and industrial agencies. The annual budget for this work exceeds a half a million dollars of which $ 375.000 comes from sources outside of the state of Texas.

E 10

REPORT ON WORK CARRIED OUT BY THE SERVICE HYDROGRAPHIQUE OF THE INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA, 1951—1954

By
JENS SMED
I.C.E.S., Service Hydrographique

Bulletin Hydrographique. This publication contains oceanographical data (temperature, salinity, pH, excess base, and the content of various constituents of sea water) collected in the North Sea, the North Atlantic and adjacent waters, mainly by institutions in member countries. During the period under consideration the issues for 1948 and 1949 were published.

Hydrographical Card Index. The card index covers the same regions as the Bulletin Hydrographique. It contains observations of temperature and salinity, taken simultaneously, together with a few minor collections of temperatures only. The card index has now been checked and carried up to date and may be considered fairly complete with regard to observations of salinity and simultaneous observations of temperature from the regions covered. Copies of card index data have been delivered on request to scientists in member countries.

Wind data for areas of the North Sea, received from the German Hydrographic Institute, have been copied and distributed regularly.

Synoptic Hydrographic Charts. This series of charts was started by Cdr. Lumby and published by the Fisheries Laboratory, Lowestoft for the period June 1950 to June 1952. The publication was then taken over by the Council and the charts have since been prepared by the Service Hydrographique of the Council.

For each month a set of four charts is published: Two charts show the distribution of surface temperature (referred to the middle of the month) and surface salinity and two charts show currents and winds as 10-day means at a network of stations. The charts for temperature, salinity and wind cover the area 47½° N.—63° N., 11° E.—21° W., i.e. North Sea, English Channel, Irish Sea and the north-eastern North Atlantic, whereas the current chart is limited to the southern North Sea and the Channel mainly. A short descriptive note accompanies the set. The charts are issued about four months after the month to which they refer.

Variation of Surface Water Temperature. Since 1876 the Danish Meteorological Institute has arranged for regular observations of surface temperatures from vessels crossing the North Atlantic. This comprehensive material, which has most kindly been placed at our disposal by Mr. Helge Thomsen, Head of the Nautical Section of the Danish Meteorological Institute, has been used for calculating temperature anomalies for 1°-squares for each month in the whole period of years from 1876 up to the present. The anomalies have been averaged over greater areas. These averages together with their yearly and 5-yearly means have been published in a series of notes in the Annales Biologiques.

It is found that for all areas north of 55° N. a conspicuous rise of temperature sets in about 1920, the temperatures reaching high values in the '30es and '40es.

With data from the same sources it has been found that in an area off the eastern coast of Scotland the temperature rise begins in the first years of the '30e. From card index data the same conclusion has been arrived at for a number of areas in the southern and Northern North Sea.

Homogeneity of Water Column in the southern North Sea. This subject was studied in order to find out in which areas surface observations of temperature and salinity were representative for the whole water column. The work was based on the data in the Hydrographical Card Index. The mean temperature difference and the mean salinity difference between surface and bottom were computed for each month and each 1°-square and recorded in monthly charts.

E 11

REPORT ON OCEAN WAVE RESEARCH CONDUCTED AT NEW YORK UNIVERSITY

By

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University of New York

For a number of years the Department of Meteorology and Oceanography has been conducting ocean wave research on the basis of empirical and theoretical studies. It has been possible to combine the principles of hydrodynamics, Fourier analysis, time series, and statistics into results which come close to representing actual wind generated gravity waves within the limitations of a linear theory.

At the present stage of ocean wave research, attempts have been made to fit the rules which govern the wave motion into a consistent framework of more complete physical and mathematical description of the sea. Since the wind generates not a single harmonic wave train, but a large number of individual wave components with different heights and wave lengths, it is extremely difficult to describe the wind generated wave pattern by means of only two single parameters e.g. "height" and "period". The characteristic feature of wind generated sea is their irregularity, that is, the ever changing pattern of "apparent waves", whose "wave lengths" and "heights" vary between certain limits. The statistical distribution of heights and periods of the apparent waves signifies the actual wave motion.

It has been shown that the wave pattern at the sea surface can be represented as a stationary Gaussian process in three variables, (x, y, t), which is characterized by a spectrum which is a function of the wave frequency and direction of travel. The spectrum of the ocean waves as a function of frequency can be defined by the assumption of an infinite number of individual wave components, which are continuously distributed between the frequency $\nu = 0$ and $\nu = \infty$ in the composite wave motion. An individual wave component is therefore explained approximately by the spec-

tral wave height H_ν as related to the spectral energy δU_ν in the interval $\nu \pm \delta\nu$ concentrated around the spectral frequency ν.

The outstanding theoretical problem is the development of laws which govern the growth of individual wave components and the representation of the spectral energy distribution at given wind velocities. Based on theoretical reasoning and on statistical analyses of visual wave observations the spectrum of ocean waves was derived in a general form as a function of frequency for different wind velocities. If the wave spectrum for given conditions (wind speed, fetch, duration) is known, the "height" and "period" characteristics of the composite wave pattern can easily be deduced. Many properties of the composite pattern of ocean waves which can be derived from the theoretical wave spectra have been verified in nature.

Explanations of the behavior of swell and the period increase observed on waves travelling out of the wave-generating area have been given.

These results provide for more reliable wave forecasting techniques based for the first time on the laws of physics and mathematical statistics. The description of the characteristics of sea and swell by means of the wave spectra is independent of the artificial definition of a fictitious equivalent wave or some kind of "significant wave". However, if wanted, such "waves" can be defined more accurately by means of the wave spectra. The wave characteristics are completely described by statistical terms, and information can be given about the average time interval between succeeding wave crests at a fixed point, the range of time intervals, the period of the most energetic wave component and of the highest swell passing a fixed point. The height characteristics similarly refer to the average height, the average height of the one-third or the one-tenth highest waves and the probability distribution of the amplitudes of the apparent waves in the composite wave motion.

Theories developed during the past few years by mathematicians and statisticians in connection with communication and noise in radio circuits have been applied to the properties of the sea surface, and this has permitted a generalization of the usual concepts of Fourier analysis so as to represent the short crested sea surface as a particular realization of a member of the ensemble of all possible states of the sea surface which can be characterized by a paticular spectrum. The sea surface can be represented by a quasi-

stationary Gaussian process as a function of space and time (x, y and t) for many hours over large areas.

One particular development has been a theory which describes the response of actual ships to actual waves in an actual seaway within the assumptions of linearity. The fact that a ship rolls with one average period and pitches with another average period is, it is believed, adequately explained by this theory.

Another very interesting development of the theory is an explanation of the outsize waves frequently encountered on the open ocean which are far higher than the usual run of waves. The number of waves which must pass before one wave with a certain maximum height will pass is predicted, but the time it will pass is not known. Work is underway in the development of a wave spectrum analyzer which will make it possible to obtain reliable wave spectra for use in the analysis and prediction of the state of the sea surface. This analyzer is based on the principles of statistics and electronics, and it will perform a proper running weighted average of the squares of the discrete Fourier components of a 20 minute wave spectrum in order to obtain best estimate of the original spectrum of the wave record.

The theory on which these results are based has been presented in a number of formal papers, and a practical manual for forecasting wind generated waves has been prepared. This manual will soon be published in a revised form by the U. S. Hydrographic Office.

A list of currently obtainable references and of papers in various stages of preparation is appended for the information of those who are attending the General Assembly of the International Union of Geodesy and Geophysics.

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E 12

OCEANOGRAPHIC PROGRAM OF THE UNIVERSITY OF WASHINGTON

By
RICHARD H. FLEMING and
CLIFFORD A. BARNES.

In 1951 the University of Washington established a Department of Oceanography that is now offering both undergraduate and graduate programs of instruction. With assistance from the Office of Naval Research the Departement is conducting an active program of surveys and research in the ocean waters of the Northeast Pacific and in the inshore waters of the state of Washington, using the 115-foot long vessel BROWN BEAR. Recent efforts have been directed towards studies of the non-parmanent water movements off the coast and to the analysis of the mechanism of water exchange in the deep and fjord-like Puget Sound and Hood Canal. Field observations and theoretical analyses are supplemented by studies on a tidal model of the inshore waters in which the tides, tidal currents and the mixing of the fresh and salt water are duplicated. Several projects involving the engineering applications of oceanography have recently been completed.

E 13

PHYSICAL OCEANOGRAPHY IN THE ARGENTINE REPUBLIC

By

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Dirección General de Navegación y Hidrografía
Buenos Aires

INTRODUCTION

Until the beginning of 1953 the study of Physical Oceanography was the responsibility of a section of the Hydrographic Division (Chart Construction). As a consequence of more elaborate military requirements for a better knowledge of the sea, which the Navy put forward, as well as the needs some organizations have for their studies of a biological nature, the Oceanographic Division was created in the «Dirección General de Navegación e Hidrografía», which is responsible for the overall oceanographic investigation of physical character to be carried out in the country. —

The oceanographic problems to be solved are numerous and various in character. —

In the field of Physical Oceanography, the Argentine Sea (Mar Argentino) is practically unknown; although we count on numerous observations on surface temperature and salinity, which allow us to construct charts with their mean values, the surface and subsurface variations suffered by the various properties are entirely unkown. — In the field of tides, the problem is more advanced, since the series of tide observations, made by tide stations during a long period, offer a more detailed knowledge of the propagation and deformation of tide waves in the Argentine Sea, and the corresponding Antarctic Sector. —

Relating to Marine Biology, the main activity in the country has been developed in the field of taxonomy and only very few studies of ecological nature has been made. —

In the field of the chemistry of sea water, the knowledge of the concentration and variation of the major and minor chemical constituents is practically nil, the greatest inconvenience being the lack of competent personnel for the purpose. —

In the field of Submarine Geology there exists an ample knowledge regarding the primary aspects of the bottom relief as well as the sediment covering it, although this occurs within the Argentine continental shelf which, owing to its great extent is actually the zone of interest. —

During the year 1953, oceanography received an extraordinary impulse, which culminated in the following steps:

1°). Creation of the Oceanographic Division in the Dirección General de Navegación y Hidrografía of the Navy Department.

2°). The University of Buenos Aires started courses of Physical Oceanography and Biological Oceanography in the Faculty of Natural and Exact Sciences.

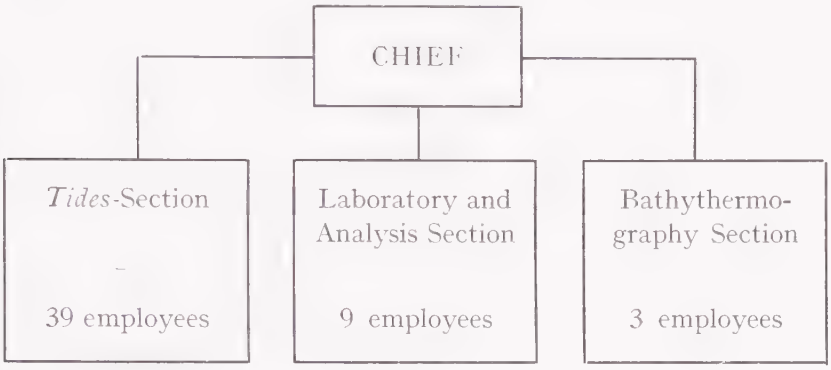
3°). The Argentine Department of Agriculture created the Fisheries Research Division.

4°). The National Institute for Research of Natural Sciences «Bernardino Rivadavia» began to prepare the laboratories and train personnel in order to deal with problems of submarine geology and chemistry of sea water, continuing also with the study of marine organisms.

Today all of the organizations mentioned above are working in perfect coordination, using their investigating power on the analysis of data obtained from the «Operation Merluza», realized during the year 1954.

ORGANIZATION AND ACTIVITIES OF THE OCEANOGRAPHIC DIVISION (1953-1954).

The organization of the Oceanographic Division of the «Dirección General de Navegación y Hidrografía» is as follows:



It is hoped that with specialized courses taking place in the Navy and the University of Buenos Aires the inconvenience which arises from the lack of technical personnel may be overcome.

The activities developed by the Oceanographic Division in the first two years can be summarized as follows:

1°). Systematic oceanographic study in the fishing areas of the Argentine Republic.
2°). Particular oceanographic study in zones of military interest for the Navy.
3°). Systematic survey in Bransfield Strait (Mar de la Flota) and Drake Passage.
4°). Studies on hydraulic model of sea ports.
5°). Systematic bathythermograph observations in the main commercial routes.
6°). Application of the I. B. M. method of punching cards for the calculation of tidal harmonic constants and geodynamic computations in physical oceanography.
7°). Effect of the ocean on the climate in the Argentine Republic.
8°). Tide prediction of Argentine ports, improved by using 42 components in place of 16 as was formerly used.

9). Study of tides and tidal currents.
10). Studies on marine sedimentation in sea harbours, shifting of sediments and influence of sand dunes on the stability of submarine topography.
11). Influence of meteorological action on the River Plate estuary.
12). Equipment of the vessel «Madryn» for oceanographic survey-work.

MODERN OCEANOGRAPHIC INSTRUMENTS

The Oceanographic Division of the Dirección General de Navegación y Hidrografía has increased its scientific wealth on the following instruments, purchased principally in Germany, U.S.A. and Great Britain:

1). Tide-Predicting Machine «Doodson-Légé» with 42 components (Great Britain).
2°). Bathythermographs (U.S.A.).
3°). Bifilar currentmeters «Böhnecke» (Germany).
4°). Emery-Dietz coring tube.
5°). Bottom sediment sampler «Snapper-type».
6°). Bottom sediment sampler «Scoopfish» (Germany).
7°). Protected and unprotected reversing thermometers (Germany and U.S.A.).
8°). Laboratory and chemical instruments (Germany and U.S.A.).
9°). Polarograph «Dr. Kunze» for chemical determination of the «nutrient salts» and other chemical compounds (Germany).
10°). Transparencymeter «Petersson-type» for the study of the coefficient of absorption in the Sea. (Germany).

The construction in Great Britain (S. G. Brown Ltd.) of a bathythermograph calibration tank, which be put in service during this year is now underway.

SEA CRUICES.

Among the various oceanographic activities carried out on the sea, the first of a series of systematic cruises to take place in the fishing areas of the Argentine Republic is noteworthy.

These cruises known under the dessignation «Operation Merluza» are carried out coordinately by all of the organizations mentioned. The fundamental objectives pursued are the determinations of:

1°). Characteristics of water masses in the zone; their seasonal variation: Sea-currents.
2°). Concentration of the nutrient salts, pH and alcalinity; seasonal variation.
3°). Plankton popluation; composition and seasonal variation
4°). Fish populations of commercial interest; their cencentration, migration and composition by age-classes. The life cycle of the mackerel and hake.
5°). Granulometric analysis of the sediments.
6°). Organic content of the sea bottom.
7°). Foraminifera content of the bottom samples.
8°). Interaction between sea and atmosphere.
9°). Drawing of fishing charts.

The first cruise was carried out during May and June 1954, covering 52 stations in about 22 days. It is expected to realize other four cruises each year in the same zone.

Part of the scientific personnel boarded the oceanographic vessel «Madryn» to which all of the tasks on physical oceanography, chemistry of sea water and records on plankton and benthos were assigned. Other part of the personnel (fishery biologists) boarded a fishing vessel and worked in the collection of fishes and the statistical sampling of the capture.

The work done on board of the oceanographic vessel «Madryn» consisted of: collecting of surface and standard depth water samples; records of temperature at the same depths; oxygen fixation; determination of phosphate, pH and alcalinity at surface and standard depths; bathythermograph observations; vertical plankton filtering; some bottom dredging and current records made with Ekman currentmeter every time the vessel anchored.

The research staffs i actually engaged in the study of data obtained and it is hoped that the results of the first cruise will be issued soon.

SUMMARY.

The outstanding progress in the development of Physical Oceanography in the Argentine Republic became apparent during the period 1953—1954, the fundamental reasons being:

1°). The development of national interest in the matter.
2°). The interest and cooperation of various national institutions having responsibility in the sea.
3°). The means of training technical personnel.
4°). The availability of an exclusively oceanographic vessel.
5°). The availability of modern instruments.
6°). The industrial and economic fishing requirements.

E 14

PHILIPPINE NATIONAL REPORT ON PHYSICAL OCEANOGRAPHY

By

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The hydrographic, tidal and other physical oceanographic investigations in Philippine waters, which used to be conducted by the Manila Field Station of the U. S. Coast and Geodetic Survey since 1901 until the outbreak of World War II, were continued by the Philippine Bureau of Coast and Geodetic Survey upon the inauguration of the Philippine Republic in 1946. However, financial and technical assistance was received from the U. S. Coast and Geodetic Survey by the newly organized bureau until the close of the Philippine Rehabilitation Program in 1950.

The results of previous and present investigations are incorporated in the 165 charts printed and issued by this Bureau and in its yearly publication of predicted tides and currents. Data on the character of the bottom and temperature and salinity observations are also available upon request.

In the interest of maritime service new hydrographic surveys were carried out by the Philippine Bureau in accordance with the following tabulation:

1947, 1948, 1949, 1952	Manila Harbor	34	sq. stat. miles
1949	Cebu Harbor	30	—«—
1950	Iloilo Strait	44	—«—
1951	San Juanico Strait	7	—«—
1951	San Pedro Bay	83	—«—
1951	Janabatas Channel	33	—«—

1952	Davao Gulf	55	sq. stat. miles
1952	Sarangani Bay	18	—«—
1952	Iligan Bay	29	—«—
1953	Ormoc Harbor	3	—«—
1953	Zamboanga Harbor	1	—«—
1953	Mariveles Harbor	3	—«—
1953	Batangas Bay	5	—«—

Hydrographic investigations of reported shoals and other dangers to navigation were also carried out.

In all the above surveys, standard methods were adopted employing echo sounding, wire drag, tag line equipment, etc.

In the field of tidal observations, the Bureau has continued the operation of five primary tide gages at Manila, Legaspi, Cebu, Jolo and Davao. In 1951 a primary tide gage was installed at Tacloban, where a peculiar tidal behavior of more than two daily high water stands was noted. Tidal stream investigations were also made by the Philippine Bureau. In 1947—1948 a weak rotary current in Manila Bay was subjected to 60-day observation. Extensive current measurements were also made in Iloilo Strait during 1949, in Cebu Harbor and San Juanico Strait during 1951. In these three current stations the stream was of the reversing type.

A significant addition to the activities of the Philippine Bureau was the acquisition of a Doodson-Legé Tide Predicting Machine in 1951. Harmonic analysis and predictions of tides and tidal streams are now being performed by the Philippine Bureau for all the important harbors of the Philippines.

The usual temperature and salinity observations at primary tide stations are being continued. Similar observations have also been made in connection with the hydrographic surveys.

E 15

RAPPORTO SUI LAVORI OCEANOGRAFICI IN ITALIA

Eseguiti nel triennio 1951—1954

Di

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Gli studi oceanografici in Italia possono essere così' riassunti:

1. Ricerche di oceanografia fisica: esse costituiscono il compito principale dell'Istituto Talassografico di Trieste e del Centro Talassografico esistente presso l'I.I. della Marina in Genova.

2. Registrazioni mareografiche e sviluppi relativi: esse hanno il loro centro presso l'Ufficio mareografico del Centro Studi del Mare in Venezia.

3. Ricerche di oceanografia biologica, che si svolgono presso varie Stazioni del Ministero di Agricoltura e in alcune altre che fanno capo al Centro Studi del Mare in Venezia e all'Istituto Naz. di Talassografia in corso di costituzione presso la Università di Padova.

1. *Ricerche di oceanografia fisica.* — Gli studi sulle variazioni secolari del *livello medio* (1), iniziatidal Prof. Vercelli sono continuati, sopratutto presso l'Ist. Talassografico di Trieste, per opera del Vercelli stesso e poi di Polli. Anche gli studi di *ottica marina* (2), con misure di trasparenza e visibilità e colore delle acque della Laguna Veneta, iniziate dal Vercelli, sono stati continuati da Polli: a questi lavori dell'Istituto Tallasografico di Trieste si aggiunge uno studio sulla depressione dell'orizzonte, di Bossolasco e Gennaro. Allo studio del le *onde* del mare (3) hanno contribuito le registrazioni sulla costa Ligure eseguite da Bossolasco, Bernasconi e Dagnino; le

ricerche di Polli nel Golfo di Trieste e quelle dell'Ist. Idr. della Marina nei suoi Osservatori meteorologici costieri; la pubblicazione di una guida pratica per lo studio della formazione, propagazione e trasformazione delle onde di Tenani. A questi lavori sulle onde si attaccano numerosi lavori sui Microsismi e la loro origine, eseguiti dall'Ist. Naz. di Geofisica in Roma.

Particolari questioni di *meteorologia marittima* (4) sono state studiate da parte di Bossolasco, Sala, Tenani, Zanon, Aliverti e Lovere.

Il Centro talassografico di Genova ha portato a termine una raccolta di elementi per lo studio delle *correnti superficiali* (5) nel Tirreno, col lancio simultaneo di numerose bottiglie nelle varie stagioni dell'anno da cinque punti centrali del mare, riassunti in una memoria di Della Croce; ha compiuto una serie di misure di *temperatura* e di *salinità* (6) delle acque per lo studio delle acque nel Mar Ligure, riassunte dal Trotti, ed ha eseguito nelle varie stagioni, su quattro trasversali, tra capo Corso e la costa Ligure una serie di Stazioni per lo studio della distribuzione della *densità* e delle *correnti* nel detto mare, anche esse riassunte dal Trotti. A tali studi si accompagnano studi di carrattere biologico riassunti da Rampi. Numerose ricerche vennero compiute sulla *conservazione delle coste* (7) delle penisole e delle isole, per opera di d'Arrigo, Lacquaniti, sia per opera di studiosi del Genio Civile, sia di studiosi isolati: Martigli e Primavera, Pancini, Visentini, Teuschl, Greco, Perdicchi, Cambi, Lippi, Boncampi, Maffi, Nilo di Villagrazia, Vatova, sia per opera dell'Ufficio Idrografico del Magistrato delle acque di Venezia, sia, sopratutto, per opera dell'I. Idrografico della Marina, con vaste operazioni di scandagliamento lungo la costa Ligure e la costa meridionale del Tirreno e nell'Adriatico sett.; queste ricerche hanno contribuito nuove conoscenze sulla topografia del fondo marino di carattere geografico e oceanografico, come quello interessante lo scambio delle acque tra il Mar Ligure e gli adiacenti bacini del Tirreno e del Mediterraneo occidentale, per opera di Bini e Trotti. Sono in corso misure sistematiche termobatimetriche nel Tirreno per lo studio delle leggi della propagazione del calore nel termoclino superficiale nell'acqua salata, a complemento dello studio, in acqua dolce, di cui a suo tempo si è occupato teoricamente e sperimentalmente il Vercelli nei laghi alpini. Tali misure vennero compiute con termobatigrafi di speciale costruzione:

un tipo speciale di termobatigrafo è in corso di esperimento per la determinazione corretta della temperatura alla superficie del mare.

2. *Ricerche mareografiche* (8). Polli si è occupato della determinazione delle correzioni meteorologiche da apportarsi alla previsione di marea di Trieste in via del tutto indipendente dalla ipotesi, di Vercelli, che esse siano dovute a sesse locali o del bacino antistante, con favorevole successo; ha poi determinato le constanti armoniche e non armoniche delle maree dall'Isola di S. Andrea sulla costa Dalmata, di Piave Vecchia, del Cavallino, di Paliaga, Torcello, Torson di sotto, Millecampi, Porto Marghera, nella laguna Veneta; ha poi proceduto al calcolo di previsioni delle maree di Trieste per gli anni 1952 e 53, allo studio della propagazione della marea nella Laguna di Venezia, e al meccanismo della sua conservazione.

L'I.I. ha pubblicato annualmente una Tavola per le previsioni delle Maree col metodo delle differenze di marea, con particolare riguardo all'Adriatico Settentrionale.

3. *Ricerche biologiche* (9) interessanti l'oceanografia fisica sono state compiute per opera di D'Ancona, Faganelli, Ranzolli e D'Errico nell'Adriatico, da Rampi nel Tirreno; ricerche geologiche (11) sono state iniziate da Segre in base ai nuovi scandagliamenti eseguiti nel Tirreno, confermando il vivo interesse ovunque riconosciuto che presentano simili ricerche par la storia naturale della terra.

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E 16

IL TRIENNIO 1952 1954 DELL'ISTITUTO TALASSOGRAFICO «F. VERCELLI» DI TRIESTE

Di

MARIO PICOTTI

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Dall'inizio del 1952 l'Istituto ha potuto disporre dell'intero edificio neo-costruito, procedendo alla distribuzione ed all'assestamento piu razionale dei laboratori e degli uffici, e ciò, a seguito dell'avvenuto trasferimento «in altra sede» dell'Osservatorio Geofisico, che vi era stato ospitato.

Ne hanno beneficiato soprattutto i laboratori di Oceanografia, Fisica e Chimica, la nuova Sezione di Spettrografia e Spettrofotometria e quella di Meteorologia.

La Sezione di Oceanografia fisica ha svolto, nel decorso triennio '52—'54, e per opera del prof. S. Polli, un'attività molto intensa nel settore mareografico, con il calcolo delle costanti armoniche e non armoniche delle maree di 24 stazioni lungo le coste italiane e la determinazione del livello medio in 19 di esse.

Gli studi di fotometria subacquea sono proseguiti nel Golfo di Trieste, nelle Lagune di Venezia e di Grado e nei laghi dell'Italia settentrionale.

La Sezione Meteorologica ha continuato il suo servizio regolare e l'Istituto dispone attualmente di 9 osservatori periferici oltre, naturalmente, a quello centrale presso l'Istituto.

La elaborazione e pubblicazione delle osservazioni meteoriche eseguite durante il lungo periodo 1841—1950 a Trieste e quasi ultimata, percui sono attualmente disponibili per gli studiosi che vi si interessano, anche questa serie ultrasecolare.

La Sezione Chimica ha compiuto un esteso rilevamento delle condizioni termo-aline del Golfo di Trieste, allo scopo di individuare

i riversamenti fluviali diretti e soprattutto quelli submarini, in relazione ai fenomeni costieri di natura carsica.

Dal materiale raccolto successivamente alla distruzione dell'Istituto — è stato possibile utilizzare la serie di misure ch'era stata effettuata contemporaneanente con tre navi nell'alto Adriatico lungo la sezione del 45° parallelo, con un paziente riordinamento dei dati rilevati a suo tempo. E' stato possibile stabilire le condizioni di ordine fisico-chimico e le stratificazioni delle aque di tale zona, nei due periodi stagionali considerati, e cioè; inverno primavera l'uno e nel corso dell'estate l'altro. Le caratteristiche fisico-chimiche delle acque sono sensibilmente diverse, perche alla costa istriana la corrente ascendente trasporta corpi d'acqua con le caratteristiche del medio e basso Adriatico, mentre lungo la costa occidentale si fa sentire intensamente l'azione fluviale.

Con una serie di laboriose ricerche e stato iniziato lo studio della presenza nell'acqua del mare degli elementi oligodinamici, biologicamente tanto importanti, unitamente ai cosidetti elementi nutritivi.

Le prime due serie di esperienze riguardano le concentrazioni del rame e del vanadio nelle acque marine e la loro distribuzione in alcune specie vegetali ed animali.

Dalle osservazioni raccolte nel Golfo di Trieste esse risultano dell'ordine di 6—7 mg/m^3 per il rame, mentre oscillano intorno a 0,1 mg/m^3 per il vanadio. Per queste determinazioni è stato impiegato il metodo spettrofotometrico e per il vanadio anche quello spettrografico quantitativo.

Oltre alle ricerche in mare sono tuttora in corso osservazioni circa il grado, la natura e la variabilità delle mineralizzazioni delle acque continentali, fluviali e lacustri dell'arco alpino orientale. In questi studi ha trovato ottima applicazione il metodo spettrografico quantitativo.

Gli studi compiuti nell'Istituto Talassografico, durante i molti anni di sua attività, sono stati oggetto di numerose pubblicazioni. La collana di esse, dal 1918 ad oggi ha superato, nello scorso anno, il numero di 300. Molte di tali pubblicazioni portano il nome del prof. Francesco Vercelli, Accademico Pontificio e membro dell'Accademia dei Lincei, che dal 18 al 52 diresse l'Istituto di Trieste, apportandovi la Sua viva, originale, intensa attività. Perciò questo Istituto porta oggi il Suo nome, a ricordo dei lunghi anni del Suo lavoro.

Il 10 giugno 1944 l'edificio principale dell'Istituto di Trieste fu distrutto completamente durante un violento bombardamento aereo. Il prof. Vercelli, rimasto sotto le macerie, ebbe la vita salva, grazie al pronto intervento delle squadre nazionali di soccorso anti-aereo, ma ne uscì, purtroppo, gravemente contuso, sì da dover successivamente ad un periodo di degenza all'Ospedale Maggiore, trascorrere un lungo periodo di convalescenza. Nell'estate successiva ritornò a Trieste e contribuì attivamente alla ricostruzione e ricostituzione dell'Istituto. Ma la Sua pur robusta fibra era stata troppo fortemente scossa, anche da dolorosissime vicende famigliari.

E nel novembre del '52 Egli si spense nella Sua casa di Camerano, piccolo borgo dell'Astigiano, dov'Egli amava riposarsi dalle fatiche del Suo intenso lavoro e dove ora riposa nel piccolo cimitero accanto ai Suoi figli strappati prematuramente da tristissima vicenda bellica e da crudele malattia, al Suo grande affetto di Padre.

E 17

SEZIONE MAREOGRAFICA DEL CENTRO DI STUDI TALASSOGRAFICI DEL C. N. R.

presso l'Istituto Talassografico «F. Vercelli» di Trieste

(Attività Triennale luglio 1951 — luglio 1954)

Di

MARIO PICOTTI

Istituto Talassografico, Trieste

La Sezione Mareografica ha per compito specifico la raccolta dei dati mareografici delle stazioni italiane, la loro elaborazione, il controllo delle stazioni stesse, il calcolo e la revisione delle costanti armoniche delle maree dei porti italiani, il calcolo dei livelli medi marini, la determinazione degli spostamenti verticali costieri e la elaborazione dei quesiti che Istituti italiani ed esteri propongono alla Sezione.

La Sezione funziona presso l'Istituto Talassografico di Trieste diretta dal Prof. Silvio Polli coadiuvato da calcolatori. Essa collabora con il Consiglio Superiore dei L. L. P. P., dal quale riceve tutti i diagrammi delle stazioni mareografiche ricostruite nel Tirreno. Con detto Consiglio la Sezione è in relazione per il ripristino delle stazioni mareografiche dello Ionio e dell'Adriatico. Collabora inoltre con l'Ufficio Idrografico del Magistrato alle Acque di Venezia per la determinazione delle costanti armoniche delle maree e dei livelli medi ed estremi delle stazioni dell'Adriatico settentrionale e delle lagune da Grado a Chioggia.

La Sezione è inoltre in relazione con l'Associazione Internazionale di Oceanografia Fisica — Comitato del Livello Medio e delle sue determinazioni — con il calcolo delle variazioni dei livelli medi marini delle stazioni mareografiche italiane, col metodo dei minimi quadrati.

Strettamente connessa con la variazione del livello medio marino è la determinazione degli spostamenti verticali costieri. Il Prof. Polli ha determinato questi spostamenti per le coste italiane e mediterranee in particolare e per quelle di tutti i continenti in generale. I risultati sono pubblicati nei lavori sotto elencati.

L'attività fondamentale della Sezione è il calcolo delle costanti armoniche e non armoniche delle maree. Nel triennio sono state calcolate, col metodo Doodson-Ammiragliato, le costanti delle seguenti stazioni:

Imperia, anno 1952, 1953.
Livorno, anno 1952, 1953.
Civitavecchia, anno 1951, 1952, 1953.
Napoli, anno 1951, 1952, 1953.
Reggio Calabria, anno 1951, 1952, 1953.
Palermo, anno 1951, 1952, 1953.
Catania, anno 1951.
Vieste, anno 1937 (completo).
Porto Marghera, anno 1940 (completo).
S. Giuliano di Mestre, anno 1933 (completo).
Valle Figheri, (Laguna di Venezia), anno 1938 (completo).
Valle Morosina (Laguna di Venezia), anno 1848 (completo).
Faro Rocchetta (Laguna di Venezia), anno 1936 (completo).
Brondolo (Laguna di Chioggia), anno 1937 (completo).
Conche (Laguna di Chioggia), anno 1934 (completo).
Botte Trezze (Laguna di Chioggia), anno 1940 (completo).
Porto Piave Vecchia, anno 1937 (3 mesi), 1939 (3 mesi).
Cavallino, anno 1939 (6 mesi).
Falconera, anno 1940 (3 mesi).
Marano Lagunare, anno 1939 (completo).
Grado, anno 1939 (6 mesi).
Barbana (Laguna di Grado), anno 1948 (completo).
Primiero (Laguna di Grado), anno 1938 (completo).
Trieste, anno 1921, 1931, 1941, 1942, 1951.

Sono stati determinati i livelli medi mensili, annui ed estremi delle seguenti stazioni:

Vieste, dal 1920 al 1943.
Ancona, dal 1920 al 1940.
Brondolo, dal 1926 al 1934.
Diga Sud Chioggia, dal 1936 al 1950.
S. Felice di Chioggia, dal 1912 al 1916 e dal 1926 al 1933.
Botte Trezze, dal 1936 al 1942.

Conche, dal 1924 al 1934.
Faro Rocchetta, anni 1918, 1924, 1944—1946.
Diga Sud Lido, dal 1920 al 1950.
Punta della Salute (Venezia), dal 1929 al 1950.
Porto Marghera, dal 1929 al 1946.
Pagliaga, dal 1924 al 1946.
Valle Dogà, anni 1945, 1946 e 1948.
Falconera, anni 1924, 1929, 1932—1934.
Porto Lignano, dal 1936 al 1950.
Marano Lagunare, dal 1929 al 1942.
Grado, dal 1930 al 1944.
Belvedere di Aquileia, dal 1936 al 1949.
Trieste, dal 1905 al 1950.

Sono stati pubblicati i lavori:

1. Polli, S. — «Le maree a Porto Marghera». Annali di Geofisica Vol. IV No 3, 387—398, 1951.
2. — — «Tabelle di previsione delle maree per il Golfo di Trieste per l'anno 1951». Ist. Talassografico, Trieste Pubbl. n° 267, 1950.
3. — — «Costanti armoniche e non armoniche delle maree di Porto Piave Vecchia e Cavallino». Archivio di Oceanografia e Limnologia, VII, 2—3, 117—128, 1951.
4. — — «Tabelle di previsione delle maree per il Golfo di Trieste per per l'anno 1952». Ist. Talassografico, Trieste, Pubbl. n° 274, 1951.
5. — — «Propagazione della marea nella laguna di Venezia». Annali di Geofisica, Vol. V, No 2, 273—292, 1952.
6. — — «Tabelle di previsione delle maree per il Golfo di Trieste per l'anno 1953». Ist. Talassografico, Trieste, Pubbl. n° 287, 1952.
7. — — «Misura dei lenti movimenti verticali della superficie terrestre» Ann. di Geofisica, Vol. V, No 3, 433—439, 1952.
8. — — «Gli attuali movimenti verticali delle coste continentali». Ann. di Geofisica, Vol. V, No 4, 597—602, Roma 1952.
9. — — «Il graduale aumento del livello del mare lungo le coste italiane» Geofisica pura e appl., Vol. 25, 123 + 129, Milano 1953.
10. — — «Tabelle di previsione delle maree per Trieste e l'Adriatico Settentrionale per l'anno 1954» Ist. Tallassografico, Trieste, Pubblicazione n° 302, 1954.
11. — — «L'attuale deformazione della crosta terrestre». Annali di Geofisica, Vol. VI, No 4, 555—560, Roma 1953.
12. — — «L'attuale aumento del livello del mare lungo le coste del Mediterraneo». Geofisica e Meteorologia, Vol. II, No 1/2, 13—16, 1954.

E 18

ESTABLISHMENT OF AN INTER-AMERICAN OCEANOGRAPHIC INSTITUTE

By
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The Pan-American Institute of Geography and History, Specialized Agency of the Organization of American States, should like very much to have the advice and counsel of the International Association of Physical Oceanography in a matter which has been referred to it for study.

At the Tenth Inter-American Conference, held in Caracas, March, 1954, a resolution was adopted entitled «Conservation of Natural Resources: The Continental Shelf and Marine Waters». At this point we are primarily concerned with the final recommendation: «The Tenth Inter-American Conference recommends to the Council of the Organization of American States the study of the possibility of establishing in the Galapagos Islands, in agreement with the Government of Ecuador, an Inter-American Oceanographic Institute which, in collaboration with other specialized organizations shall give preferential attention to scientific research in oceanography in its several fields (geological, historical, static, dynamic, biological, and economic) with a view to obtaining, through the cooperation of all the Member States, a better understanding and utulization of the natural resources of oceanic waters, submerged strata, and the subsoil». Specifically, the PAIGH has been requested by the Inter-American Economic and Social Council, to prepare a report concerning the following points: its opinion on the desirability that the Countries of America have an oceanographic institute, or special service in that field; the economic value thereof; and, from the strictly technical point of view, the best possible geographic

location of said institute (or service). We have also been asked to provide information on organizations already existing in the world which are working in this field.

Our normal procedure in the case of similar requests is to establish a small working group to study the matter in advance, and then to meet and discuss jointly their findings. The initial steps have been taken along these lines. It appears to us most desirable to bring this matter to your attention and to request your collaboration.

E 19

NATURAL DELIMITATION BETWEEN THE PACIFIC OCEAN AND THE SOUTH ATLANTIC OCEAN FOLLOWING THE ARC OF THE SOUTHERN ANTILLES

By

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The official Delegates of the Republic of Chile refer to the Association of Physical Oceanography the following proposal for submission to the 10th General Assembly of the International Union of Geodesy and Geophysics for its consideration:

«The Arc of the Southern Antilles is the natural limit between the Pacific Ocean and the South Atlantic Ocean. It passes through the Staten Island, the Burdwood bank, the Cormorant Rocks, the Black Rocks, the South Georgia Islands, the South Sandwich Island, the South Orkney Island, to touch the north-eastern end of the Antarctic Peninsula, called «O'Higgins Land» by Chile («Palmer Land» by the USA, and «Graham Land» by the U. K. and others»).

On the basis of 1) the geological connection between South America and the Antarctic Peninsula, 2) the bathymetry, 3) the great current of the South Pacific and characteristics of its waters and 4) the basis offered by marine life it is recommended:

1. General Recommendations.

a. That the following points be considered as the general rule: The delimitation of the oceanic systems should be based upon scientific-geographical antecedents.

A similar procedure should be followed for the delimitation of seas.

b. That the use of conventional lines to indicate the limits between oceans or seas (meridians and parallels) be rejected.

c. To establish that the natural delimitation between the oceans, derived from scientific research, has only definite scientific scopes aimed at reaching an exact knowledge of the structure of the Earth.

d. Suggest to the sponsoring States the preparation of bathymetrical maps of the surrounding seas in order to put up to date the Bathymetrical World Map.

e. That an adequate classification of seas be established after having revised the recommendations made by researchers and oceanographic authorities.

f. To revise the areas of the oceans and establish the limits thereof.

2. Specific Recommendations.

To establish the Southern limits between the Pacific and the South Atlantic Oceans as suggested in the Chilean proposal submitted to this Convention.

Symposium on Storm Surges

F 1

STORM SURGES

By
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Meteorological disturbances of sea level may be considered to fall into two classes: (1) those which are slowly built up and slowly decay, in a time extending over several days or even over many months, and (2) those in which the meteorological disturbance occurs within one or two days. The second type of oscillation is called a "surge", the use of this term implying both the existence of urgent forces and of a vigorous response by the sea. Its study depends upon the theory of hydrodynamics, and the object of the symposium is to provide those who are interested in practical forecasting with the results of such theory, and in return for the latter persons to provide instances of anomalies which require mathematical investigation.

Before proceeding to discuss attempts to study surges we must consider the data for the investigation, since the surge has to be separated from the tidal motion. Those who are not aware of the difficulties of predicting tides in shallow waters such as those of the North Sea may not realize that it is exceedingly difficult to predict tides accurately hour by hour owing to the so-called shallow water tides. The problem is one of slow convergence of Fourier terms in the harmonic expansion, and to the very large number of constituents within each species required to define the species, such as sixth or eighth diurnal species. Even in the absence of

obvious meteorological situations liable to cause disturbances of sea level there are residual variations of sea level after all known tidal constituents have been removed. Thirty years ago I evaluated these for Newlyn, near Land's End, for 6 months.

For January and February the hourly variations are generally small but from time to time there are fairly large residual oscillations and the same kind of thing is shown in March and April.

The question now arises whether the residue is due to imperfect prediction. A periodogram analysis of the residues was therefore made and the results show that the constituents removed in the original synthesis occur at the depressions of the periodogram so that we can confidently say that the synthesis was accurately done. Moreover, the peaks of the diagram do not correspond with any known harmonic constituent and there is nothing outstanding except for a speed half way between M_2 and L_2. I was forced to the conclusion that the large semidiurnal residues were due to free oscillations in the Atlantic ocean, but there seems to be some evidence at Newlyn to show that they involve shifts of high-water time without any obvious law, but for Liverpool a corresponding investigation has not indicated even this. One factor is that they persist from day to day, showing that there is little decay, such as there would be in shallow water.

The importance of this is that at the time when a surge is experienced there may exist these free oscillations due to very remote causes, and evidence has accumulated during the past year to show that the problem of defining a surge is by no means simple, and the problem of forecasting is made more difficult, especially if the unknown oscillation is giving a quick rise of level which is not truly associated with the meteorological situation in the adjacent seas.

However, at present we have to assume that the difference between tidal synthesis and observed level is the data for examination.

Without recourse to dynamical theory, a statistician may correlate the disturbance of sea level with barometric pressures and winds at near and remote places, and in fact many empirical formulae have been so obtained, but there was an underlying assumption that the sea level followed faithfully the variations of the forces, though experience showed that it was necessary to allow for time-

lags according to the remoteness of the place where a force was exerted. A great deal of light was thrown upon these statistical processes when dynamical investigation showed how the response depended, both in amplitude and in the time-lag, on the natural period of the sea and also revealed that every meteorological disturbance set up recurrent oscillations with decaying amplitudes. That is, the natural tendency of the water to oscillate was a factor additional to the tendency to follow faithfully the impressed forces. The period of oscillation of the basin is thus of some importance, though fortunately the oscillations decay fairly rapidly. But when sea-defences have little margin every contribution to the motion of the water needs to be considered.

Attention is drawn to the problem of the periods of oscillation in a sea such as the North Sea, with one large and one small rectangular basin. The period of the sea as a whole is important in tidal theory when a rhythm has been set up, and where the reactions of one part of the sea on the other have become settled. It may be desirable to consider the transverse oscillations of the two basins as entirely separate for the initial stages of the disturbance.

The interaction of a surge with the tide is a problem of major importance. The dynamical equations have product terms which, in the tide, explain the quarter-diurnal and other shallow water constituents, and obviously these must be considered. Again, the propagation of the tide in an increased depth of water due to the surge must be affected, but hitherto these considerations have not been sufficient to account quantitatively for the anomalies.

The stress exerted at the surface of separation between two fluids (as air and water) or between a fluid and a fixed bed (as in a river or sea) is known to be given by

$$\varrho V^2 f(\nu/Va)$$

where ϱ is the density of the fluid, moving with relative velocity V to another fluid or to a fixed bed, a is a unit of length and ν is the coefficient of viscosity. Theory does not indicate the form of the function $f(\ )$, and hydraulic engineers express the function by a single term $k\varrho V^n$
where n is usually found to be empirically somewhat less than 2 for rough pipes and river beds. Single-term representation of the function can only have a limited application. In many cases the function

$f(\ )$ becomes a constant, and it is remarkable that in many very diverse problems (in pipes, in air, and in the sea) the evidence is strongly in favour of taking

$$k = 0.0025 \quad \text{and} \quad n = 2.$$

If any observations indicate values differing from these, the explanation must be sought in the physical circumstances; for example, stratification of fluid.

Since Ekman's famous investigation on the relation of drift to wind stress, others have investigated the angle of drift in bounded seas. Forecasters would be grateful for further guidance, for if attempts are made to integrate wind-effects over a whole sea there are not enough data to satisfy statistical equations.

Observations of currents in the sea during storm surges are now being made systematically and there is no doubt that the results will be of importance in future investigations.

The matter of probability of large surges, especially when superposed on spring tides, is largely independent of all other divisions of the subject. It involves secular changes, if any, in meteorology and geodesy, and the subject is not a popular one, but engineers desire an answer to the problem that they in their turn may enter the field of probability and estimate the risks and the expense. With engineers and forecasters it is necessary to make decisions where certainty or accuracy must be related to practical considerations of expense and feasibility.

F 2

ON THE DYNAMICS OF WIND SURGES IN A BAY OR MARGINAL SEA

By

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Although existing methods of forecasting storm surges from wind fields are mainly based on an empirical footing and use very little theory, the theoretical study of the dynamics of the wind effect on sea level is not only of use for getting a better insight into the matter, but also for improving existing methods of forecasting.

The following will mainly deal with the equilibrium state.

It has been shown that the surge height, or perturbation height, or elevation — as we shall call it — at any place in a bay or partly enclosed sea area (such as the North Sea) is at any time to a fairly large degree approximated by the wind effect of the equilibrium state corresponding to the wind field of a few hours earlier, supposed the sea area under consideration is not too large. Therefore the study of the steady state is still of primary importance for the study of storm surges in such areas.

In the steady state, there is an equilibrium of the following horizontal forces, which act on a water column extending from the sea surface to the bottom: (1) the wind stress $\vec{W}$ at the top of the column; (2) the pressure gradient force (integrated from top to bottom), which is caused by the slope of the sea surface; (3) the Coriolis-force, which is proportional to any mass transport $(\vec{S})$ of the water; (4) the bottom friction; (5) the lateral friction of the moving water, which, will however, be neglected in the following.

The most simple case is the case of an enclosed sea with uniform depth D and a homogeneous wind field over it. It may be shown that the mass transport is *zero* everywhere in that case, as well as in the case where $D = \text{const.}$ and $\text{curl } \vec{W} = 0$ everywhere. If $\text{curl } \vec{W} \neq 0$ a horizontal circulation of the water is present, which complicates the interplay of forces considerably. It gives rise to a «bottom friction effect» and a «Coriolis effect».

For calculating the elevations of the sea surface the field $\vec{S}(x, y)$ is computed first from the field of $\text{curl } \vec{W}$ by means of a second order differential equation of the Poisson type, which is derived from the equations of motion by assuming that the bottom friction is proportional to $\vec{S}/D$. For some elementary sorts of inhomogeneous wind fields such calculations have been performed; f.i. for a basin of simple geometric form with a wind field which is homogeneous over each of two parts of it, having a jump at the boundary line.

If, instead of a wholly enclosed sea, we have a partly enclosed sea, or a bay, the problem becomes much more difficult because of the interaction with the ocean out-side the bay. Under certain assumptions as to the state of the open ocean, the $\vec{S}$-field and elevation field may again be calculated for the sorts of wind fields referred to above.

Further complications arise from the differences of depth of the sea area considered, and from the presence of a «leak», such as the straits of Dover is for the North Sea.

One striking effect of non-stationarity has been illustrated by charts, showing «co-disturbance lines» of the great North Sea storm surge of 31 Jan./1 Feb. 1953. During the rising stage of the surge (as a whole) there was a southward net displacement of water in the middle North Sea; during the falling stage there was a back flow to the north; as a consequence, the Coriolis force caused a piling up of water, first to the west side, later on to the east side of the North Sea (apart from the direct piling up of water by the wind, which kept the absolute surge maximum off the coast of Holland and Zeeland), the co-disturbance lines turning counterclockwise from NW—SE to SW—NE.

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Kon. Nederlands Meteorol. Inst., Rapport Stormvloed 1 Febr. 1953, 1e Ver-Volg, De Bilt 1954.

F 3

THE PREDICTION OF STORM SURGES FROM METEOROLOGICAL FORECASTS

By

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Some years ago a method of predicting storm surges at Southend was developed at the Tidal Institute based on theoretical work by Proudman and Doodson (Proudman, J. and Doodson, A. T. 1924 Proc. Lond. Math. Soc. (2),24, 140). This method allows for the oscillatory growth and decay of a surge in accordance with the period of the generating winds and the free period of the North Sea. It consisted of dividing the North Sea into sections, and integrating their surge generating potentials insofar as they affected sea level at Southend. Empirical constants were required for each section, and these were obtained from investigations of observed surges. Any method of prediction requires an assumption regarding the relationship between the tractive force of the wind and its velocity, and the law adopted was $T \propto V^2$. In the investigations and formulae the surface wind appeared in terms of the geostrophic wind, which may be forecast with reasonable accuracy.

Good results were obtained in many cases, some of which are illustrated, but the method was put aside for a number of reasons, most of them practical.

It was considered that the decay factor was such that only the first half period of a positive surge would constitute a menace to sea defences, and neglect of the oscillatory regime afforded considerable simplification in the arithmetical processes of the prediction. The number of empirical constants to be determined required a large number of surges to be available for investigation in order

to obtain good general values, and at that time there was a lack of such data. Finally, there were a limited number of occasions when the method gave poor results.

Since that time the existence of "external" surges has been well established; more recent work has shown how surge effects in the southern portion of the North Sea may be considerably effected by changes of sealevel in the English Channel. It is quite possible, therefore, that these factors may go far towards explaining the occasional early failures.

The modified method finally obtained by Corkan (Corkan, R. H. 1948 Storm surges in the North Sea, vols. 1 and 2. H. O. Misc. 15072,Washington, D. C.) was applied to many different types of surges, always with good results. When the formulae was applied to the great storm of January 31/ February 1 1953, however, although the time and height of the initial rise were adequately reproduced, the subsequent changes in level were not reproduced with the accuracy expected. This has been discussed elsewhere (Rossiter, J. R. 1954 Phil. Trans. A 915, 246).

Whilst emphasing the practical importance and value of Corkan's final formulae for Southend, it seems highly desirable that further general investigations of storm surges should revert to the oscillatory method. In particular the study of the interaction of surge and tide will be greatly facilitated by a knowledge of the differences between the most accurate predictions of surges and observations.

F 4

THE DYNAMICS OF STORM SURGES

By

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The interaction between the tide and a surge is important, but is not considered in this contribution. On taking a frictional term proportional to the depth mean value of the current, the fundamental differential equations may be reduced to the form:

$$\frac{\partial}{\partial x}(h\bar{u}) + \frac{\partial}{\partial y}(h\bar{v}) + \frac{\partial \zeta}{\partial t} = 0$$

$$\frac{\partial \bar{u}}{\partial t} + 2k\bar{u} - \gamma\bar{v} = -g\frac{\partial}{\partial x}(\zeta - \bar{\zeta})$$

$$\frac{\partial \bar{v}}{\partial t} + 2k\bar{v} + \gamma\bar{u} = -g\frac{\partial}{\partial x}(\zeta - \bar{\zeta})$$

where t denotes the time; x, y are horizontal co-ordinates and $\bar{u}$, $\bar{v}$ the corresponding components of the depth mean current; ζ is the elevation of the sea-surface, and $\bar{\zeta}$ a function of the wind and the atmospheric pressure; k is the frictional coefficient and γ the geostrophic coefficient.

Solutions of these equations are investigated for the following problems:

1. The generation, from an initial state in which $\zeta = 0$, $\bar{u} = \bar{v} = 0$, of a variable state which ultimately becomes stationary, $\bar{\zeta}$ being independent of time.

2. The decay of an initial state when $\zeta = 0$ all the time.

In terms of the solutions of these special problems, the con-

sequences of atmospheric conditions which change continuously with time may be determined by means of integrations.

For a channel of uniform depth, the problem (2) leads to a consideration of Kelvin-waves and Poincaré-waves both damped by friction, and for a rectangular gulf of uniform depth it leads to a series of these waves.

For a gulf, which is so narrow that geostrophic effects may be neglected, a general solution of the problem (1) may be stated in explicit terms.

The full text is published in:
Arch. Met. Geophys. Biokl. (A) 7, 344. (Wien, 1954).
Geophys. Supp. M. N. R. Astron. Soc. 7, 44. (London, 1954).

F 5

CERTAIN RECENT INVESTIGATIONS IN CONNECTION WITH STORM SURGES

By

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In 1941 I published a paper on wind effect on lakes and rivers. This study dealt to a great extent with steady conditions. Recently, Dr. H. Kivisild has published a paper on "Wind Effect on Shallow Bodies of Water with Special Reference to Lake Okeechobee". This paper deals with the problem of surges and set-up as a function of time. It is, thus, an extension of the investigations made by myself over 10 years ago. In Dr. Kivisild's paper referred to above interrelationships have been established between wind velocities, wind set-up, seiches, and lake, bay, or river bottom topography in shallow water. The dynamic theory is applicable for a steady set-up as well as for rapid variations, as occurring during hurricanes. Laws governing water movements in bodies of water affected by changing meteorological conditions have been expressed by using physical relationships. Empirical proof has been obtained from an application on model tests and from a full scale testing by an application on wind effect on Lake Okeechobee, Florida, U.S.A.

A hydrodynamical study of displacement of water masses has been made to establish laws for water denivellations. Differential equations governing the water surface under the action of various external forces are deduced. In order to apply the theory to irregular bottoms, a step method has been developed.

A meteorological study of relationships between air velocities and stresses has been made to determine tangential stresses acting

on water surface as a function of air velocities. The hydrodynamic drag of a free water surface has been determined by studying the results of model tests and observations in nature.

Water velocities and stresses have been related to each other by studying the mechanics of steady flow in open water under the action of bed and surface shear. The velocity distribution in equilibrium has been verified by using results of model tests. Expressions for discharge as a function of surface shear, slope and bed roughness are presented.

In shallow basins winds are a major cause for water set-up, and oscillating gravity waves may be considered separately from wind set-up in most cases, adding their influence to obtain maxima and minima of water levels. The hydromechanical, meteorological and hydrological investigations have been combined into one system of laws expressing the water flow and changes of water level in shallow basins as a function of meteorological and topographical data.

The established calculation methods have been applied for a reproduction of water movements in Lake Okeechobee during five hurricanes. A comparison of calculated and measured water levels has been made showing the applicability of the suggested calculation methods.

Suggestions for field investigations have been made which combined with the presented theory would permit a reliable estimate of the crest elevations of levees, discharge variations in rivers, discharge capacities of spillways, and heights of piers and breakwaters as far as these factors depend upon the effect of wind.

REFERENCE

H. Kivisild: Wind effect on shallow bodies of water with special reference to Lake Okeechobee, Bulletin of the Institution of Hydraulics, Royal Institute of Technology, Stockholm 1954.

F 6

DYNAMICAL INVESTIGATIONS OF STORM SURGES

By

WALTER HANSEN

German Hydrographic Institute

Proceeding from the hydro-dynamic differential equation a method is outlined which allows, using border and initial values, to ascertain step by step currents and times of high and low water, taking into account the existing forces, here the tangential stress of the wind.

For the following examples lantern-slides are shown: —

1. Drift current in a wind channel, distribution of velocity with the depth based on observations and according to theory.
2. From the wind field for the month of August over the Atlantic Ocean the transport of water masses is ascertained and compared with the surface currents derived from dead reckoning.
3. For a channel, closed at one end, the disturbance is determined for different stresses for a non-linear as well as for a linear case with the the wind suddenly occurring.
4. In a channel closed at one end, a disturbance is superposed being produced by a quickly rising wind, blowing constant for a while and then suddenly relaxing to zero.
5. For two selected profiles in the German Bight the computed disturbance-values are compared with the observations made for different wind-forces.
6. For a river estuary the tides and storm surge tides are determined numerically and compared with observations.

7. For a rectangular basin having the dimensions of the North Sea, the disturbance is ascertained for a wind field which changes with time but which is constant as regards space and which, as to velocity, corresponds to the order of magnitude of the storm of January, 1953. A comparison of the charts of the disturbance, as especially designed for this storm flood by Rossiter and Groen, reveal that the theory as applied in its simple form is able to render the basic features of the phenomena.

The afore-mentioned examples show that not only a fundamental, but in cases where a corresponding expenditure has been made, a very good conformity, expressed in percentages, can be reached between observation and theory.

F 7

WIND-EFFECTS ON THE MOTION OF THE SEA IN AN INFINITE CHANNEL AND IN A RECTANGULAR GULF

By

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The object of this investigation is to examine analytically the effect of a steady wind in producing currents and surface displacements in (a) a rotating infinite channel, and in (b) a rotating gulf, both of uniform depth.

The winds are represented as blowing either longitudinally to the channel or transversely and the resultant effects are compared.

It is shown that in the infinite channel the surface gradient in both cases is a function of the depth and at certain fixed depths is zero. The direction of the current at the surface is always inclined to the right of the direction of the wind at amounts depending upon the depth of the sea; at a great depth the angle is 45° as in Ekman's result. The transverse wind produces a much greater mean flow of water along the channel than does the longitudinal wind of the same strength.

For the numerical discussion of the motion in a rectangular gulf the width is taken as 400 km and the latitude as 50°. Three uniform depths are taken: 20, 40 and 60 fathoms. The results should throw some light on the corresponding effects in the North Sea. It is shown again that for any wind strength or direction the surface disturbance diminishes with increase of depth. A transverse wind is much more effective than the corresponding longitudinal wind in causing a surface displacement at the closed end of the sea. A longitudinal wind produces a smaller surface displacement at the closed end than it does at some distance from that end.

F 8

THE DRAG OF THE WIND ON THE SEA

By

H. CHARNOCK

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An account is given of the results and methods of recent attempts to measure the drag of the wind on the sea.

Evidence so far available is so conflicting that at no wind speed is the drag known within a factor of two: Variation of the drag with wind speed is a matter of argument, and variation with stability of the air and with state of sea or presence of currents is a matter of conjecture.

[9]

THE PROGRESS OF THE STORM SURGE OF JANUARY 31st/FEBRUARY 1st, 1953 AS INDICATED BY CURRENT METER OBSERVATIONS IN THE SOUTHERN NORTH SEA

By

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British National Institute of Oceanography

At the time of the storm, eight current meters were in operation in lightships in the southern North Sea and its environs. From their records it appears that for some days before the storm more water than usual had entered the area through the Straits of Dover (three times as much on January 30th), while off East Anglia the current had run more than usually north-eastwards, resulting in a piling-up of the waters in the middle of the sea.

Under the influence of the strong west winds of January 31st the pent-up water began to break out from the centre to the eastwards, the current off the northern Dutch coast being increased nine-fold; the inflow through the Straits of Dover persisted.

The escape of water eastwards was somewhat retarded when the wind veered to the north-westwards on February 1st, but this shift of wind placed the emphasis of the reflex upon the Straits of Dover, giving rise to the greatest reversal of current ever recorded, 28.4 miles a day towards S.W., or eight times the normal inflow.

As the wind on the two succeeding days veered first to North and then to N.E., its strength gradually fell, but it was strong enough, in conjunction with the remaining excess of water in the southern bight, to maintain a strong reverse current through the

Straits of Dover — indeed this persisted for a further four days. At the same time the current between Spurn Point and Lowestoft, which normally runs south-easterly, drove south-westerly towards the land.

A. L. Lawford: Currents of the North Sea during 1953 Gale. Weather, Vol. IX, No 3, March 1954. London 1954.

F 10

THE EFFECT OF FLOW THROUGH THE STRAIT OF DOVER ON STORM SURGES IN THE NORTH SEA

By

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British National Institute of Oceanography

It is a feature of storm surges in the southern part of the North Sea that the greatest elevation tends to occur on a line running approximately from Harwich to Flushing, the surface then sloping downwards towards the Strait of Dover, owing to the escape of water into the English Channel. From February 1953 to March 1954 a continuous record of the average flow across a vertical section of the Strait has been obtained by measurements of the voltage on a spare telephone cable. During this period there have been several occasions on which strong pulses of drift current have been superimposed on the normal tidal currents. For example, on 3 January 1954 there was a south-west going drift reaching a peak of approximately 2 knots, associated with a surge which raised the level at Lowestoft by about 5 feet. The observed rates of flow have been related to the difference in sea level between the North Sea and English Channel and to the local winds. Some indication may be given of the application of such results to the dynamical study of storm surges.

F 11

SOME REMARKS ON STORM-SURGES IN INTERIOR DANISH WATERS

By
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At the town Randers on the eastern coast of Jutland a considerable rise of the sea level has — at intervals of some years — occurred in connection with the passage of an atmospheric depression moving from west to east. It has been stated that the rise is not caused by easterly winds blowing perpendicularly to the coast.

Of course, every physical phenomenon is due to explainable physical processes even if it may be difficult to find the correct explanation. To the mentioned rise of the sea level at Randers the following explanation may be proposed: When a depression has passed Jutland from west rather strong northnortheasterly winds may blow *along* the eastern coast of Jutland, and, as the action of the wind on the waves is especially effective for shallow waters, the winds along the coast will force a great quantity of water in a southerly direction, and on account of the rotation of the earth this current of water (progressive wave) will be forced to the right and move close to the coast. When the current reaches the fjord of Randers the water moves into the fjord and produces the rise of the sea level at the town. Further south along the coast the sea level also may rise considerably, and at the island Funen (Fyn) situated near to Jutland, the current generated along the eastern coast of Jutland may also cause a considerable rise of the sea level, the water being dammed up in the area between Jutland and Funen.

The above mentioned phenomenon may be analogous to storm-

surges in the North Sea, and the above explanation may also be used for these surges and consequently be of special interest as to the large storm-surge during the night between January 31 and February 1, 1953. In this case the eastern coast of England corresponds to the eastern coast of Jutland, and the Netherlands and Belgium to Funen.

F 12

PROBABILITIES OF VERY HIGH LEVELS AT CERTAIN PORTS ON EAST COAST OF ENGLAND

By

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Hydrographic Department, Admirality

An investigation was made of the occurence of very high levels in the Tees, at King's Lynn, Yarmouth and Sheerness during a 50 year period commencing in 1901. During that period the specified high levels were reached at one or more of these ports on an average of once per annum. It was extremely rare for these levels to be reached at all four ports by a single tide and on less than half of the occasions were they reached at adjacent ports, mainly because of the differences in tidal range at each port.

For the specified level to be reached, the amount by which the sea is raised above the predicted high water level must increase with a decrease in that predicted level. Throughout the 50 year period that increase was surprisingly uniform. At King's Lynn, for example, a predicted high water level of over 14 feet was never exceeded by more than 1.5 feet, while an amount of 4 feet above prediction never occurred with a predicted level of over 12 feet. In this respect the 1953 surge was quite outstanding, but for that matter so were the strength and duration of the northerly winds which generated it.

F 13

A NUMERICAL FILTER TO REDUCE DIURNAL AND SEMIDIURNAL TIDES

By

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The purpose of the investigation is to study non-astronomic (presumably meteorologic) variations in sea level with periods larger than one day. For this purpose Mr. Gordon Groves has used a numerical filter which reduces by a factor of one thousand the rms amplitudes of the diurnal and semidiurnal tides. An array of weighting factors is applied to consecutive hourly tide values, and this array is "moved" along the record. The calculation is accomplished by punchcard methods. The weighting factors are chosen to make the filter discriminate sharply against the accurately known periods of the principal tides. The filter is independent of phase and its effectiveness depends only weakly on tidal amplitude. It can therefore be applied universally. It is found that (non-astronomic) changes in sea level by a large fraction of a foot in a few days are not uncommon, and that such changes are coherent over several hundred miles.

F 14

STORM SURGES AND INTERNAL ADJUSTMENTS IN THE WATER MASS

By

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Canadian Joint Committee on Oceanography

Observations in Halifax Harbour, have made it clear that information of an approaching tropical cyclone was given several days in advance by marked changes in bottom temperatures and salinities, brought about by shoreward movement of surface waters and offshore movement of deeper waters. This could be explained only on the basis of differences in atmospheric pressure over the ocean. Observations at Sambro Lightship, approximately ten miles off Chedabucto Head at the entrance to Halifax Harbour, also have shown that shoreward movement of the light surface water is associated with strong easterly winds blowing more than half a day, which definitely piled these waters against the coast as evidenced by sea levels in Halifax Harbour.

A considerable body of data on current and wind, general weather, and the internal structure of the water mass at Sambro Lightship has been analysed to elucidate the phenomena observed.

In summary, it has been found that:

(a) A current from an easterly direction is set up in association with the formation and subsequent movement of a tropical cyclone, and that this current brings about replacement of waters, which, observed in Halifax Harbour, gives advance information of an approaching storm.

(b) Large-scale internal adjustments in the water mass at Sambro Lightship, as shown by extensive displacements of the 5 and 10 degree isotherms, may be the result of either the direct action of local winds or the indirect action of atmospheric pressure distribution. Both actions have been observed.

F 15

PRESENT STATUS OF STORM SURGE RESEARCH IN THE UNITED STATES OF AMERICA

By

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and

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Storm surge research has been sporadic in the United States. However, studies initiated during the past three years will provide both important geographic and theoretical analyses. Promising work includes that of the following groups: (a) Reid, Freeman, and students at the Agricultural and Mechanical College of Texas on surges caused by atmospheric disturbances moving over enclosed basins, including the effect of atmospheric pressure jumps. (b) Harris of the U. S. Weather Bureau concerning the causes of wind tides and seiches in the Great Lakes. (c) Bates, Bertholf, and Burns of the U. S. Navy Hydrographic Office on the behavior of the destructive storm surge in the Gulf of Mexico on 19 March 1952.

F 16

TWO-DIMENSINAL STORM TIDES IN SHALLOW WATER

By

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Agricultural and Mechanical College of Texas

The study of finite water level changes such as those usually called „storm tides" requires the solution of non-linear differential equations. In a shallow sea of constant depth, these equations take the form

$$\frac{\partial T_x}{\partial t} + gh\frac{\partial h}{\partial x} + \frac{1}{\varrho}(\tau_{xw} - \tau_{xb}) = 0 \tag{1}$$

$$\frac{\partial T_y}{\partial t} + gh\frac{\partial h}{\partial y} + \frac{1}{\varrho}(\tau_{yw} - \tau_{yb}) = 0 \tag{2}$$

$$\frac{\partial h}{\partial t} + \frac{\partial T_x}{\partial x} + \frac{\partial T_y}{\partial y} = 0 \tag{3}$$

These equations are obtained by integrating the equations of motion and neglecting advection of water velocities. In the equations above:

a. $T_x = \int_0^h u\,dz$

b. $T_y = \int_0^h v\,dz$

c. τ_{xw}, τ_{yw} are components of the wind stress,

d. τ_{xb}, τ_{yb} are components of the bottom stress,

e. h is the height above the bottom of the basin,

f. ϱ is the density of water.

The wind stress is given and has the form

$$\tau_{xw} = X_{(x,y,t)}$$
$$\tau_{yw} = Y_{(x,y,t)} .$$

In addition, we assume that

$$\tau_{bx} = -KT_x$$
$$\tau_{by} = -KT_y$$

The usual difficulty with non-linear equations is finding a method of solution suitable for hand computation and qualitative discussion. A set of equations that approaches such suitability can be derived from equations (1) — (3). Equation (3) is multiplied by $\sqrt{gh}$ and added and subtracted from (1) and (2) to obtain

$$\frac{\partial}{\partial t}\left[T_x - \frac{2C^3}{3g}\right] + \left[C - \frac{\frac{1}{\varrho}(\tau_{xw} - \tau_{xb}) + C\frac{\partial T_y}{\partial y}}{\frac{\partial}{\partial x}\left(T_x + \frac{2C^3}{3g}\right)}\right]\frac{\partial}{\partial x}\left[T_x + \frac{2C^3}{3g}\right] = 0 \quad (4)$$

$$\frac{\partial}{\partial t}\left[T_x - \frac{2C^3}{3g}\right] + \left[-C + \frac{\frac{1}{\varrho}(\tau_{xw} - \tau_{xb}) - C\frac{\partial T_y}{\partial y}}{\frac{\partial}{\partial x}\left(T_x - \frac{2C^3}{3g}\right)}\right]\frac{\partial}{\partial x}\left[T_x - \frac{2C^3}{3g}\right] = 0 \quad (5)$$

$$\frac{\partial}{\partial t}\left[T_y + \frac{2C^3}{3g}\right] + \left[C + \frac{\frac{1}{\varrho}(\tau_{yw} - \tau_{yb}) + C\frac{\partial T_x}{\partial x}}{\frac{\partial}{\partial y}\left(T_y + \frac{2C^3}{3g}\right)}\right]\frac{\partial}{\partial y}\left[T_y + \frac{2C^3}{3g}\right] = 0 \quad (6)$$

$$\frac{\partial}{\partial t}\left[T_y - \frac{2C^3}{3g}\right] + \left[C - \frac{\frac{1}{\varrho}(\tau_{yw} - \tau_{yb}) - C\frac{\partial T_x}{\partial x}}{\frac{\partial}{\partial y}\left(T_y - \frac{2C^3}{3g}\right)}\right]\frac{\partial}{\partial y}\left[T_y - \frac{2C^3}{3g}\right] = 0 \quad (7)$$

These equations show that if we set $C = \sqrt{gh}$ then lines of constant

value of $\left[T_x + \frac{2C^3}{3g}\right]$ move with $\left[C + \frac{\frac{1}{\varrho}(\tau_{xw} - \tau_{xb}) + C\frac{\partial T_y}{\partial y}}{\frac{\partial}{\partial x}\left(T_x + \frac{2C^3}{3g}\right)}\right]$

as the speed along the x axis. Similar rules are indicated for $\left[T_x - \frac{2C^3}{3g}\right], \left[T_y + \frac{2C^3}{3g}\right], \left[T_y - \frac{2C^3}{3g}\right]$. This results in a very straight-forward computing method.

The method is applied to the tides resulting from a circular storm moving toward a straight coast.

F 17

COMBINATION EFFECTS OF METEOROLOGICAL AND ASTRONOMICAL TIDES

By

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The motion in a channel caused by meteorogical and astronomical forces is considered as the composition of a meteorological tide, an astronomical tide, and combination effects. Schematical solutions for the meteorological tide and for the astronomical tide are defined as a first approximation by neglecting the non-linear terms in the differential equations or approximating such terms by linear expressions. Then the combination effects are estimated by deducing a second approximation in an iterative process, using the first approximation. Of each of the non-linear terms in the differential equations, the effect is considered separately. The estimations are applied to a schematic model of the southern funnel-shaped part of the North Sea.

Symposium on Principles of Measuring Currents

G 1

PRINCIPLES OF MEASURING CURRENTS

By
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The manyfold variety of outward shapes of moving water entails an equal multiplicity of methods and instruments for the measurement of the direction and quantity of this movement. The limited number of physical and technical principles to be applied at all, can be combined in different ways according to the problem to be solved and the external conditions of the measurement.

The groups of principles shown below distinctly reveal the fundamental bipartition in the determination of the course which the current takes (drifting method) on the one hand, and measurement at an oceanic station (flowing-through method) on the other hand. It will be useful to classify instruments and methods according to the principles

(1) of application (ship under way or freely floating bodies — ship or instrument riding at anchor);

(2) of measuring the velocity (difference in position or drifting — pressure of current on rotating or elastically yielding surfaces etc.);

(3) of measuring the direction (difference in position — compass direction).

Further marks of distinction are of a more technical nature:

(4) Recording or indication of the measured values, manner of transfer of the measured values; further technical characteristics result from the problem:

(5) Continuity degree of measuring (single values, continuous indication or recording, mean values)

(6) Sphere of application by steps of depth and steps of velocity.

By combining in one table two or three of the most important of these characteristics, the known methods and instruments can be arranged systematically, so that the relation of similar instruments becomes obvious on the one hand, and combination possibilities which hitherto were not realized technically, will be recognized on the other hand.

G 2

NEW APPROACHES IN CURRENT-MEASURING

By

J. N. CARRUTHERS

British National Institute of Oceanography

Whereas, under conditions of calm so complete that an anchored ship remains virtually immobile, it is easy enough to make entirely satisfactory measurements of currents at all depths, the same is, of course, very far from true when there is any sea running. In order to avoid communicating to a suspended current-meter ship movements productive of registrations which do not relate to horizontal currents, instruments have often enough in the past been operated from anchored lines attached at their upper ends to buoys of good lift located well below surface.

In many cases the instruments employed and the accessories handled are so heavy that powered winches are essential, and the operations are very time-consuming as well.

For some time past it has been considered desirable to possess a simple means of measuring water movements well below surface (even very close to bottom) which would require neither the anchoring of a ship nor any power hauling. It was thought that if such a means could be devised, then very small ships or launches would suffice for the operations, and mere easy repetition of individual measurements would go some way to compensate for not getting the continuous records which are furnished by such fine (but elaborate, expensive and heavy) current-meters as the German Schaufelrad. Also a much greater spread of observing points would be possible.

Whilst the design of a very simple device which would suit was being thought over, a pressing need for one arose in connection with certain commercial fishing operations. Demersal fishing for cod by purse seine at Lofoten was the immediate concern, but it seemed more than probable that the provision of an easymeans

of learning the speed and direction of water movement at depths whereat worthwhile concentrations of off-bottom fish had been echo-located, would perhaps be of wide interest to commercial fishermen who gain their livelihood from the use of floating trawls.

In the final outcome a simple way was devised of recording the speed and direction of currents at more or less any fishable depth (even at great depths for research purposes) without the need to anchor a ship and without any call for power handling.

A verbal description will be given of the device which is a light cone made of non-magnetic mesh metal requiring only to be snooded on to a light rope having a sufficient weight at one end, and a buoy of adequate lift well below surface up above. To the buoy is attached a long length of thin line either held loosely captive on board at its other end, or attached to a small finder buoy if it be preferred (as is possible and convenient) to cast the whole lot overboard into the sea to be recovered with ease after ten minutes or so.

Details of some observations made with the "Fishermen's Current Meter" (also referred to as the "Submarine Current Cone") will be given together with a description of a very simple rope-slope-indicator specially devised for use with it. The function of the latter is to reveal the obliquity of the rope during an observation to the end that it becomes known at what height above the sea bottom a cone has worked.

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G 3

THE PADDLE-WHEEL CURRENT METER AND THE BIFILAR CURRENT METER OF THE GERMAN HYDROGRAPHIC INSTITUTE

By

J. JOSEPH

German Hydrographic Institute, Hamburg

The *paddle-wheel current meter* (*Schaufelradstrommesser*) is a self-recording measuring instrument which can be lowered down to a measuring depth of 50 m over a measuring period of 4 weeks and can be anchored at depths down to 300 m. The instrument is particularly used for the measurement of tidal streams. Its special merits are that simultaneous measurements can be made with several instruments at various depths or within a more extended sea area and that these measurements can be carried out in any weather. A built-in device for the measurement of pressure records the distance of the current meter from the surface, with other words the tides when the currents are weak and the depth at which the meter is laid out small. The technical structure and the method of laying out paddle-wheel current meters (Schaufelradstrommesser) are described and measuring examples shown.

The *bifilar current meter* (*Bifilarstrommesser*) is a measuring instrument to be operated from the anchored ship, with board indication either by a printing or a recording device. The instrument can be used down to a measuring depth of about 40 m. It is suitable for the measurement of very weak currents as well and is particularly employed when measuring the vertical distribution of the velocity of the current. It can be connected to a gyro compass and will then give the direction of the current referred to geogra-

phical North. A special advantage of the instrument lies in the possibility to record the direction continuously thus making it likewise suitable for examination of the turbulence. The technical structure of the instrument is shown.

Both these instruments together suffice for the tasks to be solved at the present time by the German Hydrographic Institute.

For routine observations on light-vessels the «Stromkreutz» and the «Carruthers-Log» have been used in recent years.

G 4

THE USE OF TOWED ELECTRODES IN SHALLOW WATER

By
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The measurement of currents in the sea by the method of towed electrodes has been described by von Arx (1950). In this country, simple equipment has been developed by the National Institute of Oceanography, and K. F. Bowden (1953) has described results on wind produces currents in deep water. Through the kindness of Dr. G. E. R. Deacon, this equipment was lent to the Fisheries Laboratory, and has been used in the shallow water of the southern North Sea. This paper deals with the results.

Von Arx drew attention to the fact that the signal from the electrodes would be smaller in shallow water than in deep water for the same current speed. Especially would this be the case in shallow water where tidal streams were the main factor, and where they were uniform from surface to bottom.

Bowden gives the expression

$$e_2 = \frac{-\varrho}{\varrho+\varrho'} E$$

where e_2 is the potential difference recorded between the electrodes, ϱ is the specific resistance of the moving water, ϱ' is the specific resistance of the return circuit through the still water and the sea-bed, and E is the e.m.f. induced in the moving water by the earth's magnetic field. For a shallow surface drift over deep water (e.g., a wind-driven layer) $\varrho' \ll \varrho$, so that

$$\frac{\varrho}{\varrho + \varrho'} \simeq 1 \text{ and}$$

$$e_2 \simeq -E = -VZl \times 10^{-8} \text{ volts,}$$

whence

$$V = \frac{-10^8}{Zl} e_2 \text{ cm/sec}$$

In shallow water, the signal e_2 will be reduced by the factor $\frac{\varrho}{\varrho + \varrho'}$

so that $$V = -\frac{\varrho + \varrho'}{\varrho} \cdot \frac{10^8}{Zl} e_2 \text{ cm/sec}$$

or $$V = Ke_2$$

The constant K can be determined by measuring e_2 by towing electrodes if V can be obtained by an independent method of current measuring.

Electrodes were towed and the signal recorded over a period of 13 hours. During this time the position of the ship was recorded by the use of a Decca Navigator System, and a method devised to deduce the drift of the ship from the Decca Meter dial readings which were taken every two minutes. The velocity of the current was calculated from twelve ½-hour drifts, and the values compared with the recorded voltages. A high degree of correlation was found to exist, and K was evaluated.

As pointed out by von Arx, the value of $\frac{\varrho}{\varrho + \varrho'}$, and hence K, may change from place to place, and its variation is the subject of further enquiry. When more exploratory work along these lines has been done, the method of towed electrodes should be applicable to the shallow waters round the British coast.

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G 5

PROPELLER AND PENDULUM FOR CURRENT MEASUREMENTS

By
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For studies of rapid fluctuations of the currents, sensitive and rapidly reacting instruments are needed. For this purpose certain experiments have been made, the results of which are demonstrated.

A pendulum is described, the deflections of which are recorded by a moving picture camera. Simultaneous records of each single revolution of an ordinary current meter propeller made direct comparison between the two principles possible. For calibration experiments a black-white decimeter scale was mounted along the entire length of the experimental tank. In this way the speed of the instruments could be determined in detail.

It results from the experiments that the deflections of the pendulum reflect the velocity variations with a retardation of about one-third of a second. In other words, the deflection at any moment represents some average of the current over an interval of two-thirds of a second or more. This «lag» is explained by the time needed for the acting forces to attain equilibrium, but may also be due to the turbulent field created by the pendulum. A similar lag was found to be present also in the propeller revolutions.

Some results obtained by the two methods in the surface tidal current of a narrow channel in Bergen are demonstrated. The construction of the new pendulum current meter for subsurface use has not yet been completed.

G 6

PRINCIPLES OF THE METHOD OF TOWED ELECTRODES

By

M. S. LONGUET-HIGGINS

If two electrodes A and B are towed in tandem behind a ship, the voltage between them, as measured by a potentiometer in the ship, equals

$$-\int_A^B \varrho\, i \cdot ds$$

where ϱ is the resistivity of the water and i is the electrical current-density. Provided that the potential gradient vanishes, $\varrho\, i$ is equal to $v \wedge H$ where v is the water velocity and H is the magnetic field. However, in order that this simple relation shall hold, there must be an easy return path for the flow of electric current. Such a path may be provided either (1) by the sea bed, if $\varrho/\varrho' \ll h/D$ (where D is the width of the stream, h is the total depth of water and ϱ' is the conductivity of the sea bed to a depth of order D), or (2) by the lower layers of the ocean, if the mean velocity in a vertical line is small compared with the surface velocity.

In the English Channel and the North Sea h/D is of the order of 1/1000, and measurements on submarine cables have shown that there is a considerable return flow of electric current through the sea bed. In the Gulf Stream system, where h/D is greater, the conductivity of the bottom is probably not important, and the return flow of current is mainly through the lower layers of the ocean.

In a recent theoretical study by H. Stommel, M. E. Stern and the present author[1] the electrical current-density has been cal-

[1] Papers in Physical Oceanography and Meteorology (in press).

culated for (1) a uniform stream of rectangular cross-section and depth h' (less than or equal to h), and (2) a stream of elliptical cross-section in water of infinite depth. It is found that there are anomalies near the edges of the stream, extending to a horizontal distance of the same order as the depth of the stream near the edge; also that if $\varrho/\varrho' \ll h/D$ there is a further anomaly extending to distances of order D from the edge of the stream.

On magnetically disturbed days natural earth-currents produce electrical gradients which in the English Channel are comparable with the gradients due to tidal streams; on magnetically quiet days the earth-currents can usually be neglected. Very little is known about the distribution of earth-currents in the ocean basins, and further observations are desirable.

G 7

OBSERVATIONAL ASPECTS OF CURRENT MEASUREMENTS BY THE ELECTROMAGNETIC METHOD

By
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Woods Hole, Massachusetts

The electromagnetic method of ocean current measurements has provided one means for studying the surface currents of small parts of the open ocean on a quasi-synoptic basis and without reference to the geostrophic approximation. Work has been going forward rather steadily for about seven years on both the shipborne applications of the method, particularly in the strong currents in the western North Atlantic, and in measurements in channels, notably the Straits of Florida and the English Channel. The largest scale measurements thus far undertaken are those made between ocean islands and the continents surrounding the North Atlantic basin.

The observations from ships have contributed to an understanding of the detailed structure of the Gulf Stream, in particular, which is found to resemble recent detailed observations of both the jet stream and the structure of atmospheric fronts in that it consists not of a continuous band of water such as that in a river but rather a succession of disconnected filaments arranged en echelon.

The measurements of electric potential across channels have been related to the volume transport of water through the channel. This has led to interesting new evidence of tidal oscillations and fluctuations in the volume transport of the Gulf Stream, in the Straits of Florida and of the tidal streams of the English Channel.

In the open ocean electrical fluctuations of the tidal period have also been detected which may be related to the open ocean tides.

Efforts with shipborne apparatus have also shown usefulness as a means for improving the dead reckoning of ships crossing powerful ocean currents. The transverse surface velocity profile of one of these currents, i. e. the Gulf Stream, has been observed repeatedly and shows a sharply peaked flow structure resembling that of the atmospheric jet stream. The intensity of cyclonic shear in the zone to the left of the current maximum is in all known cases equal to or greater than the magnitude of the local Coriolis parameter. In the zone of anticyclonic shear to the right, the intensity of shear has not been observed to exceed the value of the local Coriolis parameter.

The reliability of electromagnetic measurements of ocean currents from shipboard has been tested in as many ways as possible. Generally the method has been found to give consistently good indications of the direction of flow in strong currents but somewhat less than the actual speed. The deficit of indicated speed is known to be related to the ratio of the thickness of the ocean current structure to the total depth of water. Using navigational means for comparison, it has been possible to measure this deficit and by suitable integrations to estimate the volume transport beneath the line of the ship's traverse.

Instrumentation has remained simple on shipboard consisting of three essential components, namely: a recording potentiometer of suitable range, a pair of silver-silver chloride electrodes mounted on a neutrally buoyant two-conductor electric cable, and the ship's compass. In land based installations it has been found that special electrode materials can be dispensed with unless the potentials must be measured with the highest degree of refinement.

Papers

H 1

THE EFFECT OF WIND ON TIDAL CURRENTS

By

K. F. BOWDEN

British National Institute of Oceanography

In shallow and restricted waters where the movements are normally dominated by strong tidal currents, drift currents induced by the wind differ in several respects from those in the open ocean. The effect of the earth's rotation becomes less important compared with the effects of bottom friction and of surface gradients due to the piling up of water against the coasts. The presence of tidal currents, moreover, increases the eddy viscosity and the bottom frictional stress for a given drift velocity. The characteristics of the drift currents are closely related to the changes in sea level produced by the wind, and it seems an advantage to investigate them together where possible.

Some observations on these lines have been made possible by measurements of the voltage on a submarine telephone cable across the Strait of Dover. The voltage recorded is proportional to the average velocity of flow across a vertical section. Continuous records have been obtained during the period from February 1953 to March 1954. From December 1953 to March 1954, recordings were also made on a cable from Aldeburgh to Domburg. The tidal currents are the most prominent feature of the records and, since their magnitude is known from other measurements, they provide a means of calibration.

The drift currents, found by eliminating the tidal currents, have been correlated with the local wind and with the slope of the sea surface between the eastern part of the English Channel and the southern part of the North Sea, as deduced from tide-gauge records. This has been done for 25-hour periods, centred at noon, for the whole duration of the observations, while a more detailed analysis, similar to that used for storm surges, has been applied to selected periods of unusually strong flow. It is found that, in the Strait of Dover, the flow is influenced to a greater extent by the differences in sea level than by the local wind. The differences in level, however, are themselves due largely to the effect of winds over large areas such as the North Sea or English Channel as a whole.

H 2

RELEVES DE LA DENSITE DE L'EAU DE MER A LA STATION MAREMETRIQUE DE MARSEILLE

Par

L. CAHIERRE

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Lorsque le Service du Nivellement Général de la France (NGF) a installé à Marseille un marégraphe destiné à définir le zéro du réseau du NGF, il a été préscrit à l'observateur d'effectuer chaque jour une mesure de la densité de l'eau de mer.

La Section du Nivellement de Précision possède dans ses archives les résultats des mesures effectuées depuis 1895. Une partie de ces mesures (1930—1939) a été exploitée par le C^{t} Rouch (La température et la salinité de l'eau de mer à Marseille et à Monaco. — Bulletin de l'Institut Océanographique, 21 juin 1941).

Comme l'a fait remarquer le C^{t} Rouch, ces mesures ne sont pas tres précises, étant faites simplement au moyen d'un aréomètre plongé dans une éprouvette qu'on vient de remplir d'eau puisée à proximité du puits du marégraphe. Mais on dispose actuellement de plus de 20.000 observations, ce qui permet d'obtenir une précision intéressante sur les moyennes.

La température de l'eau est mesurée en même temps, et on constate une corrélation, qu'on savait exister, entre la densité et la température. Ceci a permis d'étudier la valeur des observations, et de mettre en évidence des anomalies dans les mesures de densité depuis avril 1924 jusqu'à novembre 1925. Comme on n'a rien retrouvé dans les archives qui puisse expliquer ces anomalies, on a laissé de côté les observations faites en 1924 et 1925.

Les moyennes annuelles des densités son comprises entre 1,02720 et 1,02830, tandis que les moyennes annuelles des températures sont comprises entre 15° et 18°7.

Les moyennes des moyennes mensuelles, calculées sur l'ensemble des années d'observations, donnent:

	Densité	Température
Janvier	1,02850	12°6
Février	1,02854	12°2
Mars	1,02840	13°4
Avril	1,02810	14°9
Mai	1,02759	16°8
Juin	1,02712	19°4
Juillet	1,02692	21°5
Août	1,02694	21°6
Septembre	1,02707	20°6
Octobre	1,02747	18°2
Novembre	1,02793	15°8
Décembre	1,02830	13°7
moyenne G^{ale}	1,02774	16°7

Si on fait un graphique en portant les températures en abscisses et les densités en ordonnées, les points représentatifs sont tres voisins d'une droite dont le coefficient angulaire est — 0,00018 pour 1 degré. Le coefficient de corrélation est 0,994.

Dans la zone de températures où les mesures ont été effectuées, on peut résumer ces résultats par la formule suivante:

$$d = 1{,}02805 - 0{,}000018\ (\theta - 15°).$$

H 3

FILM ON OCEAN TIDES

shown by
A. T. DOODSON
Liverpool Observatory and Tidal Institute

This film is a 16 mm copy of a film prepared from drawings by the late Dr. Barton. It was intended for popular lectures, and it gives pictorial representation of elementary principles of tidal forces, tide gauges, tide records. Then an ingenious scheme of shading is applied to illustrate the movement of tides in estuaries, seas and oceans. The diagrams are based partly upon the cotidal charts by Harris, and partly upon inferences by Barton. The representation of tides in the oceans cannot be accepted as accurate but the film illustrates the possible value of such methods for demonstrating the complexities of tidal motion.

H 4

THE TRANSLATION INTO HARMONIC FORM OF LUBBOCK'S METHOD FOR THE PREDICTION OF HIGH AND LOW WATERS, AND THE APPLICATION TO ANALYSIS AND PREDICTION OF PUNCHED-CARD MACHINES

By

W. HORN

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A new method has recently been introduced for the prediction of high and low waters, or of lunar-hourly heights of tide, in German ports. The tides in these ports are of a markedly semidiurnal character, and largely distorted by shallow-water effects, so that the ordinary harmonic method which aims at a mathematical representation of the total tide curve proves impracticable.

The new method resembles Lubbock's nonharmonic method in that the required times and heights are obtained directly by adding variable „inequalities" to the respective mean lunitidal intervals and mean heights. These inequalities are separately analysed into sums of trigonometric terms of which a selection of about 44 has proved to supply a satisfactory approximation. The constants involved have been derived from 19 year observations, by applying the rule of least squares. Punched-card machines are employed in performing the numerical work of analysis as well as prediction.

H 4.1

LES MAREES DU LAC LEMAN

Par

P.-L. MERCANTON

Lausanne

Les seiches, ces oscillations libres des nappes d'eau, des lacs notamment, ont été depuis F. A. Forel l'objet d'investigations nombreuses; on est, en revanche, insuffisament renseigné sur leurs marées, oscillations forcées. Sans interêt pratique et de plus difficiles à déceler en raison de leurs amplitudes minimes, ces marées n'ont été que rarement reconnues. (Michigan, Lentz 1879 Léman, Mercanton 1948). Le Service fédéral suisse des Eaux, à l'occasion d'une étude très serrée des denivellations du Léman vient d'apporter une contribution décisive à nos connaissances. Ce Service a maintenu en fonctionnement de novembre 1949 à fin décembre 1950 un ensemble de quatorze stations limnigraphiques réparties autour du Lac et semblablement équipées d'enrigestreurs inscrivant les niveaux à 1/2 et à la minute près. Ces stations ont fourni autant de tracés qui rassemblés sur un même diagramme y ont dessiné un faisceau presentant de multiples irrégularités d'epaisseur et d'aspect. Ces irrégularités trahissent précisément les denivellations alterant, pour des causes diverses, les vents surtout, l'èquilibre hydrostatique de la nappe. Par temps calme et lac tranquille le faisceau de limnigrammes montre toutefois constamment des renflements régulièrement espacés d'environ 6.2 heures, précisément la moitié de la périod de la marée astronomique semidiurne. Un examen approfondi rèvèle que ces nodisités sont imputables assentiellement aux traces des stations extrêmes du lac. Les stations intermédiaires n'y ont que peu de part ou même aucune, comme Thonon, dont le linigramme ne reflète que les variations lentes du niveau général des eaux règlées par le régime du Rhône.

A Bellevue près de Genève, en phase de syzygie, on a observé la marée avec une amplitude totale moyenne de 4.9 mm. (27 valeurs); à Chillon, près de l'extrémité orientale du Léman on avait alors 4.4 mm. (25 obs.). A la même époque à St.-Prex, en face de Thonon, on n'avait que 2.6 mm. (9 valeurs) et à Thonon même la mareé est de demeurée toujours imperceptible.

Le «Tidal Institute» de Liverpool a bien voulu soumettre a l'analyseur harmonique les relevés horaires de niveau d'un mois lunaire en huit stations des deux rives du lac. Les constantes trouvées ne laissent aucun doute: le Léman est le siège d'une marée à rythme semidiurne prépondérant. Cette marée, d'èquilibre, se traduit par un balancement incessant du lac, de bout en bout, prenant ainsi le caractère d'une seiche longitudinale permanente, d'impulsion astronomique de la masse lacustre. L'analyse révèle en outre que les eaux de Thonon figurent une pseudo-amphidromie. Tout semble se passer comme si la surface du Léman, supposée rigide, effectuait en 12 h 25 minutes une oscillation complète autour de Thonon, son point de fixation. Trois lignes cotidales aboutissant à cette région d'immobilité illustreraient cette situation. L'une débuterait près de Genève et suivrait à peu près l'axe du Petit-Lac, la seconde traverse le Grand-Lac à partir de la rive septentrionale, entre Morges et St.-Sulpice; la troisième partirait de Cully. Ces cotidales extrêmes sont les lieux des élongations maximales et de sens opposés des oscillations; la ligne médiane est l'axe du balancement. Cette image de la marée lémanique sugerée à M. Doodson par l'examen sommaire de la constante M2 n'est, bien entendu, donnée par lui que sous toutes réserves, car devant l'agitation incessante de la surface lacustre même par temps calme, la faiblesse de la marée restreint singulièrement la précision des constantes maré-mètriques cherchées.

H 4.2

SUR LA RECHERCHE DANS LES ARCHIVES ANCIENNES DE DONNEES SUR LES ANCIENS NIVEAUX DES MERS

Par

JEAN LEGRAND

M. Jean Legrand, qui poursuit depuis de longues années des recherches sur les variations séculaires de niveau moyen de la mer en exploitant les documents d'archives a pu établir les résultats suivants pour les côtes françaises:

Par rapport a sa valeur au XIX siècle le niveau moyen était inferieur d'environ un demi-metre vers les années 1100 et 1400, superieur d'au moins autant vers 1200 et 1512. Depuis cette dernière date il s'est abaissé jusqu'à retrouver la valeur de référence pendant la période 1600—1660, il est ensuite remonté d'un demimetre jusque vers 1700 et est déscendu d'autant entre 1720 et 1750.

Pour obtenir ces résultats M. Legrand a examiné et discuté minutieusement de nombreux documents qu'il a retrouvé dans les archives des services public français et dans les bibliothèques, notamment des rapports d'inspecteurs, de plans d'ouvrages maritimes, des bris de travaux, etc.

H 5

OPPORTUNITE D'ENREGISTREMENTS DE LONGUE DUREE DES ONDES INTERNES

Par

PIERRE BERNARD

Institut de Physique du Globe de Paris

Parmi les nombreuses hypothèses émises sur la cause initiale des oscillations internes, certaines font intervenir des influences atmosphériques. Par exemple, Takegami a calculé l'effet d'une perturbation atmosphérique mobile, et Hans Pettersson a mis en évidence une corrélation entre la vitesse du vent et l'amplitude du mouvement de la couche de transition du Gullmarfjord, tandis que Sandstrøm a expérimenté sur la déformation due au vent à la surface de séparation de deux liquides superposés dans un bassin fermé.

Si une origine météorologique des mouvements internes de la mer devait être envisagée, on observerait une variation saisonnière de leur intensité. Or, quelques observations permettent de considérer comme possible une telle variation, comme la remarque de major Seiwell qui trouve les écarts entre les profondeurs extrêmes d'une isotherme plus grands en hiver qu'en été, mais une série continue de mesures d'une durée d'au moins un an dans des conditions favorables serait nécessaire pour établir définitivement ce résultat.

Ces mesures pourraient être faites suivant la méthode d'Idrac, au moyen de thermographes enregistreurs immergés à plusieurs profondeurs suffisamment rapprochées pour que leurs indications permettent de déterminer sans sondages auxiliaires le gradient vertical de la température, indispensable pour réduire les oscillations thermiques en amplitudes de déplacements.

Sans entrer dans l'examen des possibilités pratiques de telles

observations, l'auteur souligne le caractère entièrement nouveau des données qu'elles fourniraient sur le phénomène des ondes internes; des progrès peuvent en résulter dans les domaines où elles trouvent une application.

H 6

THE STATISTICAL DISTRIBUTION OF WAVE HEIGHTS

By

R. W. BURLING

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The statistical distribution of wave heights on the surface of a reservoir is compared with the theoretical distribution for a narrow wave spectrum. There is good agreement provided very short-period waves are neglected.

H 6.1

DIRECTIONALITY OF WAVES MEASURED BY SHIP-BORNE WAVE RECORDER

By
D. E. CARTWRIGHT

In connection with Dr. Longuet-Higgins' paper, the following preliminary results from recent trials with the British National Institute of Oceanography's ship-borne wave recorder may be of interest. These trials were suggested by Dr. Longuet-Higgins and consisted in recording the waves passing the ship as it steered round a course in the shape of a regular 12-sided figure. The ship's speed was 7 knots, and each side took about 10 minutes. From the Doppler changes in the spectra of «frequency of encounter», it was hoped to obtain a 2-dimensional spectrum of the waves present.

Two circuits were made on different days, and the spectra were obtained with the A.R.L. Automatic Fourier Analyser. These spectra show in each case a single outstanding band of high energy density which clearly moves systematically with the change of course, and corresponds to the dominant waves due to the local wind. The rest of the spectrum consists for the most part of low energy density whose movements are not easy to follow. In one set of records, however, it is possible to identify also a small isolated band of low frequency, corresponding to a long swell.

The mean fequencies of these bands are shown plotted against course in the accompanying lantern slide, and it is clear that they follow quite closely the sinusoidal law prescribed by elementary theory. In each case the best possible sine curve (allowing for slight changes in ship's speed) is shown, and from it can be obtained: the true frequency, given by the mean; the phase velocity, given by the amplitude; and the direction, given by the phase angle.

In all three cases the phase velocities are fairly close to the classical values appropriate to the true frequencies, but are actually about 7 % less. However, this discrepancy may be due to a systematic error in the ship's log. The directions of the two main components correspond roughly with those of the prevailing winds, and the swell band appears to originate from a distant previous storm in the Southern hemipshere, though this has not been checked.

It may be possible eventually to analyse more fully the complete spectra, but this is a more difficult process, and there are some serious obstacles which for brevity's sake will not be described here.

H 7

DIRECTION-FINDING IN SEA WAVES

By
M. S. LONGUET-HIGGINS
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The normal method of recording wave height or pressure at one point only does not determine the direction of travel of the waves. But N. F. Barber has recently shown that from N differently spaced pairs of recorders one can find the first N harmonics of the distribution of wave energy, considered as a function of the direction of wave travel. An approximation to the desired energy distribution is then provided by summing the first N terms of its Fourier series. However, this approximation may give some negative (i.e. impossible) values for the energy. In the present paper we show how further information can be obtained using the property that the energy is always positive. The results are most likely to be useful in detecting one or more bands of energy which are narrowly concentrated in direction, such as the swell from distant storms.

H 8

THE TSUNAMIS CAUSED BY THE MYOJIN EXPLOSIONS

By

HISASHI MIYOSHI AND YOSHIO AKIBA

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From September 1952, Myojin Sho (a submarine reef 31° 56.7' N, 140° 0.5' E) continued to explode. Accompanying every explosion, big or small tsunamis are inferred to have been generated. But the nearest island is so far from the reef, that no damage was caused. At Hachijo Island (130 km north of Myojin), one of nearest islands, we had a self registering wave recorder. This caught the bigger tsunamis. These records show the character of Cauchy-Poisson waves started from the origins of finite regions. And there exists a remarkable node in every record. The present authors inferred the positions of these nodes to indicate the difference of the path-lengths along which tsunamis had travelled. Aoga Shima which lies between Myojin Sho and Hachijo Island is supposed to have played a prism-like action.

H 9

GENERATION OF THE TSUNAMI IN THE COMPRESSIBLE WATER

By

HISASHI MIYOSHI

Geographical Institute, Tokyo University

The horizontal and the vertical dimensions of the bottom deformation which causes the tsunami, are, judging from the refraction diagram and the total energy of the tsunami caught along the coast, supposed to be of several hundred kilometers and several meters respectively. And the vertical velocity of the bottom deformation is considered to be as rapid, from analogies, as that of the phenomena of the fault on the land. As the sea water is compressible, there will always occur waves of expansion in the water, which is distinct from the gravitational wave and the energy of which is comparable to that of the latter. Consequently, the surface elevates or depresses accompanying an oscillation up and downwards. The period of this oscillation is the time required for the sound wave to travel between bottom and surface four times, and is the order of that of the usual swell. In this paper, we treated this disturbance of the compressional waves mathematically.

H 10

HIGH FREQUENCY OCEAN WAVES

By

W. MUNK

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The high frequency tail of the ocean wave spectrum has been studied by measurements of slope and curvature statistics. The high frequency components have a broad directional beam width, with considerable energy travelling 60° to either side of the wind. The slope statistics is in agreement with an elevation spectrum proposed by Neuman, but not with a spectrum proposed by Darbyshire.

H 11

ON THE RESULT OF WAVE OBSERVATIONS AT JOGASHIMA ISLAND AND ITS APPLICATION TO WAVE FORECASTING

By

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S. UNOKI AND Y. KUGA

Central Meteorological Observatory, Tokyo

Some investigations were made on the wave height and wave period of wind waves and swells, based on the data of continuos observation of ocean waves with a self-registering wave gauge at Jogashima Island, Kanagawa Prefecture, Japan, during a year from September 1951 to August 1952, and the characteristics of variations of wave height and wave period and their relations to meteorological conditions were made clear. These results of analysis are also available for forecasting ocean waves. The variations of wave height and wave period can be classified into six types as shown in Fig. 5 schematically, and each of these types corresponds to a particular meteorological change, respectively. The points which have become known up to now are as follows:

(1) In case a cyclone moves eastwards on the Pacific side of Honshu, Japan, the change of waves of "Type I" or "Type II" occurs at Jogashima Island, and the positions of the cyclonic centre at the time when the waves begin to become high, at the time when the wave height becomes maximum and at the time when the waves begin to decay at Jogashima Island are shown in Fig. 8. Again, the positions of the cyclonic centre at the time when the wave period becomes maximum are shown in Fig. 9. Further, the

maximum wave height, the duration of higher waves, etc. and their relations to the intensity and distance of the cyclone are shown in Figs. 10—12.

(2) In case a cyclone moves eastward on the Japan Sea side of Honshu, the change of waves of "Type III" or "Type IV" occurs at Jogashima Island, and the maximum wave height, the duration of higher waves, etc. in that case are shown in Figs. 16—19.

(3) In case a migratory anticyclone covers Honshu, the change of waves of "Type V" or "Type IV" occurs at Jogashima Island. And Fig. 23 shows the extent of area covered by this migratory anticyclone when the sea is calm at Jogashima Island.

(4) In case the station under consideration is within the sphere of influence of Ogasawara Anticyclone, the change of waves is complicated, depending upon the nature of the sphere of influence. In this case, the change of waves of "Type V" or "Type VI" generally occurs, with incidental occurrence of the change of "Type III". And, we can see from Fig. 25 the extent of area under the influence of this anticyclone when the sea is calm at Jogashima Island.

[Figures not received].

H 12

ON THE SECONDARY UNDULATION OF BAY OF NAGASAKI

By
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Nagasaki Marine Observatory

In the Bay of Nagasaki there frequently occurs the conspicuous secondary undulation with the amplitude about 2 meters and the period about 30 minutes. The authors began to study this phenomenon by the actual observation of tide at various points along the coast of the bay and compared with the theory. The result coincides, in the first approximation, with the theoretical treatment. But this theory deals only with the stationary feature of the secondary undulation and it is difficult to deal with the transient phenomenon of the undulation as is actually observed, because the actual one is caused by some external forces. To discuss this point the hydrodynamical experiments were done using the model of the bay, 1/3000 in horizontal scale and 1/100 in vertical scale and the feature of the forced oscillation were clarified. Then an electrical L-C-R network has been designed to have analogies to the hydraulic oscillation systems.

In order to have the knowledge of the forced oscillation, the electrical pulse voltages having similarities to the actual hydraulic external forces were fed to the suitable terminals of the network by a photoelectrical wave generator. The solutions of the forced oscillation are illustrated on a cathoderay oscillograph and the feature of the oscillation is compared with the actually observed record of the tide gauge. Thus the feature of the actual external force is expected from this electrical method.

Comparing with the meteorological data and the weather map, we noticed that the pressure jump may be taken as an external force of the conspicuous oscillation. The external force may exert on the sea water generating the long wave and so if the pressure distribution over the western sea of Japan is proper, the above generated long waves may converge to the Bay of Nagasaki and cause the observed phenomena and so the oscillation may be forecasted from the weather map.

H 13

A SHIPBORNE WAVE RECORDER

By

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British National Institute of Oceanography

Experience in wave recording at sea has shown that accurate information on the height and period of ocean waves, and detailed studies of wave generation, propagation, and attenuation in different conditions of wind, depth and tidal stress, require a wave recorder which is incorporated in the hull of a ship and does not require buoys and wires which are difficult to handle in bad weather.

Such a wave recorder has been used in the «Discovery II» and in the Ocean Weather Ship «Weather Explorer». It consists of a measuring head fixed inside a small hole in the ship's hull, which measures the height of a wave above the hole by its response to the water pressure. The doubly integrated output of an accelerometer mounted in the same position measures the vertical displacement of the pressure recorder above an arbitratry reference level, and the outputs of the pressure recorder and integrated accelerometer added together give a reliable wave record.

H 13.1

LABORATORY STUDIES OF GRAVITY WAVES GENERATED BY THE MOVEMENT OF A SUBMERGED BODY

By
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Wave Research Laboratory, University of California

In order to gain some insight into the phenomenon of gravity water waves generated by underwater siesmic disturbances, the Tsunami, a laboratory study was made of the waves resulting from an idealized two dimensional model of the movement of a submerged body. Bodies of several shapes, sizes and weights were allowed to drop vertically or to slide down inclines of several angles, in water of various depths, from several heights above the bottom. The surface time histories were recorded at a point close to the origin of the disturbance, and at a point or points some distance from the origin. In addition, motion pictures were taken of several of the tests. It was found that a crest always formed first, followed by a trough from one to three times the amplitude of the first crest (depending primarily upon the slope of the incline), followed by a crest with about the same amplitude as the trough. Due to the dispersive qualities of the waves, additional crests and troughs continued to form with increasing distance from the origin. The magnitude of the amplitudes depended primarily upon the submerged weight of the body, but also upon the submergence, the water depth and other characteristics of the generation. Within the limits of experimental conditions, it was found that time interval between the first and second crests remained constant

regardless of the water depth, the distance of fall, the weight of the body or the time of the fall. It was, however, found to be related to the length of the body, with the period increasing with increasing length, and to the slope of the incline, with the smaller the incline, the greater the period.

H 13.2

UNE METHODE SIMPLIFIEE POUR L'ETUDE DE LA PROPAGATION DE LA HOULE

Par

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La méthode simplifiée développée au cours de l'exposé permet de résoudre facilement certains problèmes de propagation de la houle. En particulier, l'action d'obstacles réfléchissants ou absorbants peut être étudiée de cette façon. Naturellement, les résultats obtenus sont approchés, et ne sont valables que dans le domaine de validité de la méthode, étant donné les hypothèses faites au départ.

Ces hypothèses sont les suivantes:

1. Le phénomene étudié est à deux dimensions.
2. Ou se limite au cas d'une houle de faible amplitude.

La facon d'utiliser la méthode et le parti que l'on peut en tirer sont mis en lumière par l'étude des problèmes suivants: transmission de la houle à travers une résistance visqueuse ou quadratique, action d'un ouvrage en dérivation sur un canal (résonateurs, poche d'air), effet d'une variation brusque de profondeur ou d'un seuil, transmission d'une houle à travers un passage en charge.

Ces exemples montrent que la méthode simplifiée exposée permet dans certains cas de résoudre des problèmes difficilement traitables par une méthode rigoureuse, dans d'autres cas, d'obtenir des renseignements sur la façon d'agir des divers paramètres en cause.

H 14

ACTION DES VENTS SUR LE COURANT ATLANTIQUE EN MEDITERRANEE

ET

FACTEURS PHYSICO-CHIMIQUES DE LA FERTILITE MARINE (*Plancton*) AU LARGE DE L'ALGERIE

Par

F. BERNARD

Professeur à la Faculté des Sciences, Alger

Plus de 2.000 échantillons d'eau, prélevés de 0 à 500 m au large de l'Algérie, de 3 à 50 milles au nord des côtes, de 1950 à 1953, serve de base à l'étude du courant atlantique permanent venu de Gibraltar.

Les niveaux suivants: 0, 10, 25, 35, 50, 75, 100, 200, 300, 400 et 500 mètres ont fait l'objet des prises. Nous y avons déterminé: la température (thermomètres Richter), la salinité (méthode de Knudsen), la teneur en phosphates, en nitrates (à la strychnine réduite) et en nannoplancton (au microscope inversé). Les opérations portent sur la plupart des mois de l'année, et, d'Ouest en Est, ont eu lieu au large de Nemours, Oran, Mostaganem, Ténès, Cherchell, Alger, Dellys.

A Nemours (mer d'Alboran) l'eau est encore presqu'entierement océanique par tous les vents. D'Oran à Dellys (soit sur environ 500 km), il y a un fort pourcentage d'eaux méditerranéennes, très nettement influencé par la météorologie locale. On peut schématiquement distinguer 3 grandes catégories à cet égard d'apres les vents moyens précédant les prises durant 48 heures, et leur action sur les couches marines de 0 à 200 m.:

1° Par vent dominant du secteur Ouest (de N inclus à SW inclus),

faisant au moins 2 m/sec., il y a partout au moins 70 % d'eaux atlantiques, avec un maximum de 100 % et une moyenne de 85 %. Les eaux méditerranéennes font le reste, car il y a fort peu d'eaux de mélange.

2/ Par temps calme (vent moyen inférieur à 2 m/sec.), le pourcentage méditerranéen passe de 15 à 29 %, et les zones de mélange restent rares.

3/ Par dominance d'Est ou du Sud (de S—SW à N—NE inclus), les eaux méditerranéennes montent à 34 % et les atlantiques font encore 51 %. Il y a ici 15 % d'eaux de mélange ou supposées telles (salinités entre 37 et 37,5‰), tres favorisées par ces vents opposés au courant océanique.

Les vents agissent aussi sur la profondeur moyenne du courant atlantique, qui ne dépasse guere 80 m. par vents forts, qu'ils soient d'E ou d'W, et peut atteindre 200 m. par temps calme (où le vent côtier n'a pas tendance à faire remonter les eaux méditerranéennes profondes). Par vent fort, le courant a donc tendance à s'étaler beaucoup en largeur.

Nos études sur la fertilité sont basées sur les organismes dominants dans chaque litre d'eau entre 0 et 500 m, au nord des côtes algériennes, entre Nemours à l'Ouest et Dellys à l'Est. Les prises d'eau sont faites en général de 3 à 25 milles du littoral. Fixée au formol neutre, l'eau est examinée au microscope inversé.

Dans les 2.000 échantillons dénombrés jusqu'ici, l'espèce prépondérante est le loin *Coccolithus fragilis* Lohm., sous forme de cellules flagellées, de spores ou de palmellas (stade de division gélatineux, sans flagelles). Elle est pérenne et fait en moyenne plus de 60% du volume de phytoplancton par litre. Jointe aux autres Coccolithophorides, elle l'emporte très nettement sur les Péridiniens (rares audessous de 25 m) et sur les Myxophycées (certains *Nostoc* peuvent parfois atteindre 26 millions d'éléments par litre). Les Diatomées sont pratiquement négligeables ici.

Ce plancton à Flagellés calcaires est-il avantagé par le courant atlantique permanent de la région? Oui, car sa densité au litre et celle des phophates sont en moyenne deux fois plus grandes là que dans les eaux méditerranéennes de même profondeur. Mais il y a en Méditerranée, surtout vers la Tunisie, plus d'espèces de toute nature que dans le flux océanique, de composition qualitative bien

plus monotone. En outre, la transparence des eaux est deux fois plus grande en Méditerranée proprement dite: outre son agitation, le courant atlantique contient nettement plus de plancton et de particules en suspension. Son opacité parait avoir peu d'importance pour les *Coccolithus*, espèces autotrophes en surface (leur optimum lumineux est situé entre 30 et 50 mètres) mais hétérotrophes en profondeur (maximum quantitatif entre 300 et 600 métres, c'est à dire en zone purement méditerranéenne parcourue par le contre-courant très salé venu de la Méditerranée orientale).

D'une façon générale, pour être fertile (et par conséquent nutritive pour le zooplancton et les larves de Poissons), l'eau requiert à la fois un minimum de mouvements et d'échanges et une certaine stabilité de composition. La division des Flagellés calcaires, moins facile que celle des Diatomées, paraît arrêtée ou ralentie par des changements, même assez faibles, de température et de salinité. Elle est également ralentie dans les eaux trop calmes, où le manque de courants empêche le renouvellement des phosphates, des matières organiques et de tout le cycle vital marin.

C'est pourquoi les couches les plus riches correspondent au courant d'eau méditerranéenne profonde apportant des eaux orientales vers Gibraltar. Là, il y a simultanément de la circulation, du renouvellement nutritif, et un milieu physico-chimique assez constant (températures de 13°2 à 13°6, salinité de 38.55 à 38.90‰).

Ce genre de recherches doit donc tenir compte, non seulement du milieu physique à un moment donné, mais aussi de la durée de cet état de choses, car il faut 10 à 15 jours de conditions stables, sans perturbation, pour que le stock d'organismes par litre devienne important et supérieur à 2 milligrammes de matière vivante.

H 14.1

CURRENT CONDITIONS IN THE NORWEGIAN SEA BASED ON RECENT MATERIAL

By

J. EGGVIN

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The oceanographical research in the Norwegian Sea can be devided into 3 periods, namely 1876—78, 1900—04 and from 1949 on.

During the last mentioned period the Institute of Marine Research of the Norwegian Directorate of Fisheries have made 20 cruises in the area by help of the "G. O. Sars" and 5 hired vessels.

Investigations have been carried out also in areas, from which only few or none observations, especially in the deep water, occurred before.

The working up of the material shows that the currents vary partly from what has been shown in former current maps. The distribution of different watermasses can be explained by new features of the bottom configuration.

H 15

ZONAL OCEAN CURRENTS DRIVEN BY WINDS

By

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An ocean completely covering a rotating globe is assumed. A planetary wind distribution is then determined from actual data in the central region of the Pacific Ocean and a zonal oceanic circulation driven by this wind system computed dynamically. The problem is two-dimensional and confined in a meridional plane. Zones of upwelling and sinking are also located.

H 16

ON THE CIRCULATION OF THE SURFACE LAYERS OFF THE EAST COAST OF INDIA

By

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Studies of the density structure of the surface layers off the East Coast of India have established the fact that there are distinct seasonal water masses. The lowest density, *Northern Dilute Water*, occurs about October and the highest, *Southern Bengal Water*, about March. Because of their widely separated origin and density they can be used to explain the horizontal and vertical circulations of the Western Bay of Bengal.

In the fall, approximately 10^{12} cubic meters of fresh water are emptied into the northern part of the Bay of Bengal. Most of the surface-diluted sea water is confined to the coast by the prevailing wind system which also creates a southwesterly circulation. This accumulation of low density water causes sinking of the heavier layers over the continental shelf.

Prevailing winds reverse during the spring season and develop a circulation to the northeast. The runoff is greatly reduced, and the denser *South Bay of Bengal* water is brought into the area. During this season, the transport is away from shore causing a band of upwelled water adjacent to the coast. Summer and winter water masses, though slightly warmer and colder, are largely transitions between the two above extremes.

The seasonal change in water masses results in the largest annual sea level cycle in the world. The vertical range in water level of

nearly two feet can be accounted for largely by seasonal changes in the vertical density of the two water masses and to a small extent by the differences in atmospheric pressure from one side of the Bay to the other.

Other circulations are reflected in the large diurnal and semi-diurnal internal waves and a phenomenon described as "rotary currents". The latter are manifested at the surface by wide bands of alternately smooth and rough water. A cross-section of temperature structure shows sharp upward and downward displacements of the isotherms associated with the surface bands. The circulation is concluded to be interlocking spirals or "rotary cells". These are believed associated with the boundary of the tidal currents across the continental shelf and the prevailing along-shore current.

H 18

LES COURANTS MARINS DE SURFACE DANS LE BASSIN OCCIDENTAL DE LA MEDITERRANEE

Par

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Depuis le mois de janvier 1951, à raison de deux campagnes par an, (janvier et juillet) la détermination de la direction des courants marins est effectuée dans le bassin occidental de la Méditerranée, en utilisant des flotteurs dérivants largués en des points fixés à l'avance, par les paquebots des lignes régulières françaises.

De janvier 1951 à juillet 1952, nous avons utilisé comme flotteurs, des bouteilles lestées d'une contenance de 250 cm^3; à partir janvier 1953 nous leur avons substitué des pochettes en chlorure de vinyle. Les bouteilles étaient larguées à raison de 1000 par an puis le nombre de pochettes a été doublé et c'est ainsi qu'à l'heure actuelle, 5 000 flotteurs ont été largués. Chaque flotteur, bouteille ou pochette, contient une carte postale que le découvreur remplit et nous renvoie. Pour l'ensemble du bassin occidental de la Méditerranée, le nombre de réponse varie suivant les saisons entre 13 et 20 % pour les bouteilles et entre 4 et 8% pour les pochettes. Ce pourcentage varie avec les régions, c'est ainsi qu'entre la France, la Corse et l'Italie, il peut dépasser 30% mais qu'au large des Baléares il tombe à 1%. Dans l'appréciation des directions de courant par cette méthode, il s'introduit des erreurs qui peuvent être supprimées grâce à un grand nombre de flotteurs. On peut également avoir une notion de la vitesse des courants.

L'interprétation des résultats nous a conduit aux conclusions suivantes:

En été, le long de la côte de l'Afrique du Nord, de Gibraltar au détroit de Sicile, coule un courant de 1 noeud environ. A la hauteur de Bizerte, ce courant se divise en deux branches, l'une se dirige vers la Méditerranée orientale (0,5 noeud) et l'autre dans la mer Tyrrhénienne (0,4 noeud). Cette dernière branche, à la hauteur de Palerme tourne vers le NW et traverse toute la mer Tyrrhénienne avec une vitesse de l'ordre de 0,2 noeud. Le long de la côte italienne coule vers le SE un contre courant, un autre descend vers le Sud le long de la côte de la Sardaigne. Le courant principal pénètre dans le golfe de Gênes entre la Corse et l'Ile d'Elbe, il suit le littoral de l'Italie puis celui de la côte d'Azur française. A la hauteur des iles d'Hyères, il se divise en 2 branches, l'une continue à longer le littoral tandis que l'autre se dirige vers le sud est, rejoint les côtes de la Corse et remonte vers le Nord Est pour former ainsi un vaste tourbillon dont le centre est situé à mi-chemin entre Nice et Calvi. La branche occidentale continue à suivre le littoral et aprés le golfe du Lion longe les côtes espagnoles. Dans la zone comprise entre les Baléares et la Sardaigne les courants sont faibles et de direction variable sauf au large des côtes de Sardaigne où un courant de 0,4 noeud se dirige vers le SE et vient rejoindre celui qui longe le littoral de l'Afrique du Nord.

La différence entre le régime d'été et celui d'hiver est peu importante. En hiver, la vitesse des courant est généralement plus faible. On note quelques différences dans les directions, c'est ainsi qu'au large des côtes occidentales de Sardaigne la direction du courant est plus orientée vers le Sud et le tourbillon au large de la Côte d'Azur est moins étendu.

H 19

VARIATIONS IN THE STRENGTH OF THE ATLANTIC CURRENT IN THE FAROE-SHETLAND CHANNEL

By

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Among the several water-masses of different geographical origin which converge upon seas of north-west Europe, and doubtless influence in greater or less degree the fisheries of these seas, that which probably exercises the major influence is the oceanic water-mass borne by the Atlantic Current through the Faroe-Shetland Channel. Reliable quantitative measure of this influence therefore seems desirable if such can be obtained.

In the Faroe-Shetland Channel, and particularly over the Wyville Thomson Ridge which marks its threshold from the Atlantic Ocean, the Atlantic Current is, by reasons also of its lateral restriction in this region, probably most susceptible of measurement. By an assumption of zero horizontal current at the mean depth of the Wyville Thomson Ridge, which assumption has since been supported by current meter measurements, quantitative measure of the Atlantic Current between the Butt of Lewis and Faroe Bank, in the form of volume transport computations has been made in some twenty instances between 1927 and 1952, by the known marine hydrodynamical method stemming from Bjerknes's Circulation Theorem.

Such are the known uncertainties of the method, however, that corroboration of these measurements has been sought and obtained by similar computation along an approximately parallel hydrogra-

phic section between the Faroe Islands and Shetland, on the assumption, in this case, of zero horizontal current along the 35,00 $^{0}/_{00}$ isohaline. The assumption is again at least partially justified by current meter data.

In all cases, in which these two hydrographic sections have been worked approximately simultaneously, remarkably close agreement in oceanic water volume transport has been achieved. The results further indicate not only enormous translations of oceanic water northwards, but also very large fluctuations in the intensity of the Atlantic Current, thus expressed, between roughly corresponding periods of different years, from 1927 to 1952 inclusive, and also, and no less, as between different seasons of the same year, the autumn-winter intensities in the latter circumstance often greatly exceeding those of the previous and/or following spring season.

H 20

A STUDY ON THE FOAMING OF SEA WATER

By

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In spite of the fact that many marine observers are aware that sea water has a remarkable foaming capacity, there has been few scientific studies on this subject. However, the foaming capacity may be of considerable importance in oceanography. The state of sea is commonly expressed by Beaufort scale. Foaming of sea water is one of the basic evidence of this scale. Experiments have been performed on the foaming natures of sea water and of solutions of various inorganic electrolytes at varying temperature and concentrations. The procedure was as follows: A glass ampule containing filtered sample of solutions was vibrated up and down by means of a motor about 15 times per second in the amplitude of 15 mm for about 30 seconds. After the vibration was ceased, the features of foam layers were taken into photograph in illuminating with an ultra high-pressure mercury lamp. The results obtained are summarized as follows:

a. When the chlorinity of sea water is held at a constant value, the height of foam layer «H» increases slightly with increasing temperatures in a linear relation (within the range of 3—33°C).
b. Under a constant temperature, «H» increases exponentially with chlorinity.
c. Inorganic acids are almost non-foamy.
d. On the other hand, «H» in solution of salts or alkalies increases with increasing concentration, up to a certain maximum, and

then it decreases with further increase of concentration. This maximum value has been observed in concentration below 1N in the majority of solutions tested, although the corresponding concentration differs for different kinds of electrolytes.

e. The velocity of the decay of foam layer is proportional to the foam height at the time moment considered, namely, it is of the type of the 1-st order chemical reaction.

f. The stability of foam layer on the white crested waves *in situ* was considered at various points by using, i. e. half life of foam layer of sea water.

g. In the frequency distribution of foam size in the foam layer at various periods, there exists some maximum frequency. Foam sizes of maximum frequency increases with time up to a certain limit.

h. The mean radius of foam increases linearly with time as expressed by the empirical formula:

$$\bar{r} = 0.33 + 0.018 \text{ t mm}$$

where r is the mean radius of foams in the layer at the temperature $20 \pm 1°C$ and with the chlorinity $14.42‰$.

i. By using the relationships obtained in (g) and (h), the mean lives of various radii of foam are calculated. Foams with diameter less than 0.2 mm are the most unstable ones; they easily coagulate with each other, then grow up.

j. In the process of the decay of foam layer, the author has considered the same quantity «A» as the activation energy in chemical changes. «A» increases with increasing concentration, up to a certain maximum, and then decreases with further increase of concentration.

k. He has also introduced a quantity of «equivalent radius of foam» and using it has discussed the phenomenon of the decay of foam layer.

H 22

PROGRAMME DE RECHERCHES SUR LES POSSIBILITES DE MIGRATIONS DE L'OXYGENE DANS LES PROFONDEURS

Par

J. BOURCART

Professeur à la Sorbonne

Les récents travaux de MM. Fage et Brouardel ont montré que la quantité d'oxygène dissout dans l'eau de mer diminuait, en Méditerranée, d'une façon considérable au voisinage du fond. Les observations que nous avons pu faire en baie de Villefranche nous ont montré que cette diminution provenait à la fois de la consommation par le plancton et de la décomposition du "nuage" des particules organiques.

Mais de nombreuses observations montrent que dans les cañons, ou dans d'autres positions remarquables, la population planctonique est surabondante au fond.

La fixation des diatomées sur les grains de sable nous amène à penser que, dans une mer stratifiée, le ravitaillement en oxygène peut se faire par le sable soit enlevé au littoral soit apporté par les courants de turbidité des fleuves quand les courants circulent à droite du littoral.

Ces grains de sable enveloppés d'air peuvent être considérés comme des "ludions" et, du fait variations de pression, subir des montées et des descentes. Il est possible que les nombreux étalements des photographies planctoniques soient dus à de tels grains qui peuvent même jouer un rôle dans la constitution de la D. S. L.

H 23

DEEP SEA OCEANOGRAPHY AND BIOLOGICAL PRODUCTIVITY OF SHALLOW SEAS

By

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Search has failed to find local causes for the large variations in phosphate content and biological productivity of the English Channel in the last thirty years. It would seem that the cause must be sought in the circulation of the Atlantic including the deep water. Much deep Atlantic water is formed by mixing and cooling of water over the Faroe-Iceland Ridge and flows southwards banked against the Eastern slope of the Reykjanes Ridge. Some of this water descends to below 3 000 m depth. It is presumed that the amount of this deep water formed varies from year to year. Room for this water to the southward has to be found, in part by upward displacement of water already present. In years of much upward displacement following cold winters around Iceland, large reserves of nutrients will be raised nearer the surface to become available to plants and in due course to all marine animals. Following mild Iceland winters there will be less formation of the deep water, less upward displacement, and reduced supply of nutrients and poor productivity in the English Channel.

The full paper will appear in the Proceedings of the (U. S.) National Academy of Sciences.

H 24

THE PHYSICAL CHARACTER OF SOME DEEP SEA OOZES

By

A. A. DAY

A series of short cores up to $2^1/_2$ m. long has been collected in the Eastern North Atlantic from R.R.S. Discovery II and H.M.S. Challenger. Simple gravity corers were used, and only in the latest work have liners been placed in the core barrel.

The cores from the deep, nearly flat parts of the ocean basin off the British Isles were very similar to those described by Bramlette and Bradley. The average thickness of the top layer of globigerina ooze is approximately 70 cms. The glacial sediment below usually includes a number of pebbles of greater than 4 mm. median diameter, some possessing visible stiriations.

Several cores have been collected from the mountainous area of the Mid Atlantic Ridge between 47°N and 55°N, largely while the corer was being used in an unsuccessful attempt to obtain specimens of the solid rocks of the Ridge. Bare rock surfaces appear to be common especially on the tops and the steeper slopes of seamounts, and small «pockets» of sediment are enclosed in depressions in these surfaces. The cores from this area vary greatly in their nature and composition. The most important conclusion at present resulting from this study is that considerable sediment transport has taken place away from the core localities probably due both to bottom currents preventing normal sedimentation and also due to sliding of masses of sediment towards the deeper valleys.

Macro- and microscopic investigation of the nature and surface shape of the sand and gravel present in the core material showed that they were derived from the volcanic and gneissic terrains of Britain, Iceland and Greenland, by iceberg transport. No pebbles were found which could with any certainty be said to have broken off the seamounts and become incorporated in the sediment.

H 24.1

NUTRIENT BUDGET IN THE OCEAN

By
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The development of all life depends directly or indirectly upon the availability of certain nutrients required for plant growth. For marine life the ultimate source of these nutrients is provided by runoff from the land areas. However, the total annual use of nutrients in the sea far exceeds the supply from land and the difference must be balanced by regeneration and reuse. In addition to biological utilization, nutrients are lost by deposition of organic materials in the sediments. It is apparent that under long term equilibriation conditions the average annual loss of nutrients by permanent burial must be equal to the average annual increment of new materials from the land. This view is supported quantitatively by computations based on abundance of nitrogen compounds, phosphorus, and silicon in rivers, sea water, and sediments.

H 24.2

TENEUR EN O_2 DE L'EAU AU VOISINAGE DU FOND

Par

LOUIS FAGE

L'an dernier à Liverpool j'avais fait part des recherches entreprises, au large de Monaco, avec mon collaborateur le Dr. J. BROUARDEL, sur la brusque diminution de la teneur en 0_2 de l'eau au proche voisinage du fond. Ces recherches ont été continuées et apportent de nouvelles précisions sur ce phénomène. En voici un court résumé:

1°. En employant un carottier transparent, en plexiglas, ouvert aux deux bouts et fermé à la remontée par un clapet supérieur nous avons pu faire par siphonage avec un fin tube de verre, des prélèvements d'eau à des distances exactement déterminés au-dessus de la carotte désormais visible (5—10—25—40—55 cm). En outre, un prélèvement d'eau était fait dans une bouteille fixée sur le câble du carottier à 6 m du sédiment.

Les analyses sur des fonds de 100 à 304 m ont donné en moyenne les résultats suivants:

6	0,55	0,40	0,25	0,10	0,05	0,01	m
6,92	6,91	6,88	6,84	6,83	6,78	6,59	mg/l

La perte d'0_2 est peu sensible jusqu'à 0,50 m au-dessus du fond; mais à partir de ce niveau jusqu'à 1 cm du sédiment elle est de 0,32 mg/l soit de 5 %.

2°. Mais, si l'on emploi un tube de même matière (60 cm de longueur et 7 cm de diamètre) descendu *lentement* sur le fond afin de ne pas troubler le sédiment, au contact duquel deux clapets assurent sa fermeture, le clapet inférieur découpant la pellicule de

sédiment ainsi maintenue au fond du carottier, les résultats obtenus sont encore plus précis. Ils donnent en moyenne pour des fonds de 85 à 430 m les teneurs suivantes:

40	25	10	5	1	cm
7,21	7,05	6,86	6,73	6,49	mg/l

Soit, dans cette couche de 40 cm d'épaisseur, une perte d'0_2 de 0,72 mg/l, égale à — 10 %. Ainsi au fur et à mesure que les techniques de prélèvement s'améliorent, la perte d'0_2 au voisinage du sédiment apparaît plus nette et plus rapide. Notre intention est d'étendre ces observations à des profondeurs plus grandes à bord de la «Calypso».

Il résulte des récentes observations publiées par Francis A. Richards et Alfred C. Redfield dans *Deep Sea Research* qu'il existe un rapport inverse entre la teneur en 0_2 de l'eau au voisinage des sédiments et la teneur en matiere organique de ces derniers. Nous avons alors essayé de déterminer à quelle vitesse se font des phénomènes d'oxydation qui en sont la cause. Dans un bac rempli d'eau de mer de teneur en 0_2 connue dans lequel sont introduits 30 l de sédiment prélevé au large et passé à l'étuve à 110°C, on constate que, dans la couche d'eau de 1 cm d'épaisseur au contact du sédiment, la teneur en 0_2 s'abaisse si rapidement qu'au bout de 30 heures alle a diminué de moitié; au bout de trois jours, elle n'est plus que de l'ordre du milligramme et, au bout de neuf jours, elle est si faible qu'elle ne peut plus être mise en évidence par des méthodes sensibles au 2/100e de milligramme: cette couche d'eau ne contient pratiquement plus d'oxygène. Pendant le même temps, la couche située seulement à 10 cm au-dessus n'a perdu que 0,5 mg.

Ainsi sont mises en évidence, d'une part, la très grande rapidité d'oxydation du sédiment et, d'autre part, l'extrême lenteur de diffusion du gaz dissous. Ce qui est de nature à expliquer que la chute rapide de la teneur en 0_2 observée *in situ*, ne se produit qu'au proche voisinage du sédiment.

H 25

AREAS OF DIVERGENCE AND CONVERGENCE OF WIND STRESSES IN THE PACIFIC AS THE POSSIBLE INDICATORS OF UPWELLING AND SINKING

By

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Distribution of wind stresses over the Pacific Ocean is computed from the wind roses given on the Pilot Charts of the U. S. Hydrographic Office. The divergence of wind stresses is then calculated all over this Ocean and the areas of convergences and divergences are located. An area of divergence suggests the existence of upwelling, while that of convergence gives an indication that the sea water is sinking there. These results will be not only significant in dynamical oceanography but also from the standpoint of marine biology and fisheries.

H 26

THE TOPOGRAPHY OF THE MID-ATLANTIC RIDGE

By

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During the survey work of H. M. S. CHALLENGER in 1953, numerous east-to-west crossings of the mid-Atlantic ridge were made between 46°30'N and 47°45'N. The topography of the ridge in this region is very rough and only one clear feature can be observed which is common to all sections. There is a deep central trench running approximately N — S; the depth of the bottom of the trench is between 3,300 and 7,700 m. On either side the depth rises to about 2,000 m. Apart from this trench there is no correlation between the various features in spite of the east to west lines being at most 15 miles apart.

H 28

THE USE OF THE TYNDALL EFFECT FOR STUDYING PARTICULATE MATTER IN THE SEA

By
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In the Tyndall meter a parallel beam of light is projected into the water sample and the intensity of the light scattered by suspended particles at an angle of 45° is studied. The significance of the Tyndall reading is realized by the fact that for a given type of particles $> 3\ \mu$ the reading is proportional to their total surface. With smaller sizes the scattering decreases relatively in intensity and also becomes more and more selective. Numerous Tyndall measurements have revealed that the selective part of the scattering by suspended matter in natural waters is only a few per cent.

Experiments have been conducted in order to determine for red light the relationship between Tyndall reading and total surface for different types of matter suspended in the sea, such as calcareous, siliceous, detrital matter etc. The surface values were derived from microscopic measurements. The tests show that, if an average factor in the relationship is adopted for all kinds of particles with no regard to sizes below one μ, departures from this mean value of $\pm$ 30 % appear. But, as the suspended matter in the sea is a mixture of various kinds of particles, the determination of its total surface by means of the Tyndall meter gives a higher degree of exactitude.

The advantages of expressing the content of particles in terms of their total surface is emphasized.

H 28.1

THE TRANSPORT OF SUSPENDED MATTER BY TIDAL STREAMS

By

J. JOSEPH

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At two anchoring stations of the VFS «Gauss» northwest of Texel, beside hydrographical investigations, measurements of distribution of sinking particles and extinction measurements were carried out during 25 hours, giving good insight into the time- and special distribution of suspensoids in these parts of the North Sea. Observations can be interpreted as a wave of suspensoids, wandering from the ground to surface in the tidal rhythm and considerably influenced in its march by the vertical distribution of density. Values of «Austausch» are calculated under various hydrographic conditions. A mean value of 115 cm^2sec^{-1} has been found, variations of this value depending more on hydrographic conditions than on the velocity of the current. The «Austausch» decreases near the Sprungschicht to about 10 cm^2sec^{-1}.

H 20

THE SALINITY OF THE INTERSTITIAL WATER IN RECENT BALTIC SEDIMENTS

By

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As a rule the sediment cores in the Baltic contain a more or less stratified organic mud at the top, then varved clay, and finally sand or gravel. Exceptional silty layers occur imbedded in the mud or the clay.

The salinity of the interstitial water at the top of the cores is equal to the salinity of the bottom water today, and the variations of the salinity with depth are rather insignificant in the organic mud. This is disconcerting in view of the generally accepted opinion that the Baltic was a freshwater lake during one stage of its post-glacial history, viz. the *Ancylus* stage. It is possible that diffusion, or the action of bottom-living animals, has removed the salinity minimum that may at one time have existed; on the other hand it is possible that the bottom water remained salt during the *Ancylus* stage.

In the varved clay the salinity changes very considerably with depth in some areas, whereas it is more or less constant in others. *In south Baltic* the salinity is about 15 $^0/_{00}$ at the top of the varved clay, 125 cm below the top of the core, and then it decreases to about 6$^0/_{00}$ at the interface between clay and sand, 1 200 cm below the top of the core.. The vertical salinity gradient increases with depth and amounts to 0.026$^0/_{00}$ per cm immediately above the sand layer. In the sand layer the salinity is constant but for irregular variations. *East of Gotland* the salinity is 12.1 $^0/_{00}$ at the top of the core and decreases to 9.4$^0/_{00}$ at a depth of 1 000 cm; here there is

a slow decrease of the salinity with depth even in the mud layer. The core does not extend to the sand layer, and it appears probable that a longer core would display a continued decrease of the salinity. *North of Gotland* the salinity is 10.2 ‰ at the top of the core, increases to 11.4 ‰ at 500 cm, and decreases in the varved clay to 10.6 ‰ at the top of the moraine, at 1450 cm. *Northwest of Gotland* the salinity increases from 8.4 ‰ at the top of the varved clay, at 50 cm, to 11.7 ‰ at the top of the moraine, at 820 cm.

It appears inevitable to conclude that the Baltic contained sea water during the icelake stage and even that the salinity of the bottom water in one area at least was greater at one period of the icelake stage than it is at present. The formation of varves is inconsistent with a high salinity, but a salinity less than 14 or 15 ‰ might be permissible; it is also possible that the icelake contained a sufficiently thick surface layer of brackish water to make the formation of varves possible in spite of a comparatively high salinity in the bottom water.

The full paper will be published in Tellus, Stockholm.

H 30

SUR QUELQUES PHENOMENES PARTICULIERS OBSERVES AU COURS DES CAMPAGNES D'OCEANOGRAPHIE ET D'HYDROGRAPHIE LITTORALES

Par

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SAFI (MAROC FRANCAIS). Action des courants de houle.

Les résultats de la Mission d'Etudes du Port de SAFI ont été exposés en détail dans une communication présentée au Congrès de BRUXELLES, en 1951.

Les observations réalisées ont permis de dégager l'action prépondérante des courants de houle sur les transports de sédiments.

L'évolution, ample et rapide, des profils d'estran et des petits fonds, qui contrastait avec la stabilité des fonds supérieurs à la cote — 8 m, nous a conduits à admettre la notion d'une isobathe critique, qui s'est trouvée correspondre à l'enveloppe extérieure de la zone de déferlement.

Par ailleurs, nous avons noté que dans des fonds de 21 m, à l'extérieur de la jetée principale, l'amas de sable grossier, d'origine littorale, constitué par les produits de dragage, culminait régulièrement à la cote —13.

AGADIR (MAROC FRANCAIS). Flèche de sable.

La notion d'isobathe critique, dégagée au cours des études réalisées à SAFI, a permis d'expliquer le mécanisme de formation de la flèche de sable qui prolonge la grande jetée.

La mission a, de plus, expliqué le mécanisme du pivotement de cette flèche, vers l'intérieur du port.

Embouchure de l'OUED SEBOU (MAROC FRANCAIS). Evolution d'un seuil d'estuaire.

Il se formait, entre les jetées, un seuil, ou barre, à la cote —2 environ, seuil que l'on était obligé de draguer très fréquemment, car il se reformait rapidement, pour mantenir ouverts les accès des ports de MEHDIA et de PORT LYAUTEY, installés sur les berges du fleuve.

Les observations effectuées par la Mission du Laboratoire ont permis de définir le mécanisme de l'évolution de ce seuil, en période de basses eaux du fleuve: en vive eau, il se produit une action de déblayage, tandis qu'en morte eau, le seuil se reforme.

Enfin, la mission a montré que l'origine des matériaux était presque exclusivement fluviatile, et non maritime, comme on le pensait antérieurement.

Rade de TANGER. Influence d'un grand ouvrage de protection sur les phénomènes de Sédimentation.

La mission a réussi à mettre en évidence les deux phénomènes fondamentaux suivants;

1°) — un stock sédimentaire, autrefois entretenu par des apports venus de l'Ouest, a été isolé, en rade de TANGER, par la construction de la grande jetée;

2°) — une rotation de ce stock sédimentaire de l'Est vers l'Ouest s'est produite, par suite de la rupture — par la présence de l'ouvrage en question — de l'état d'équilibre préexistant, la houle ne pouvant plus contrecarrer les effets du fort vent local d'Est, bien connu à TANGER.

ARCILA (MAROC ESPAGNOL). Modification de l'état d'équilibre d'une côte par la construction d'ouvrages d'abri.

L'abri naturel, dans lequel les profondeurs s'entretenaient, sous l'influence des actions de déblayage de la houle, s'est ensablé rapidement des que des ouvrages ont été construits pour améliorer la protection du plan d'eau.

La collaboration des spécialistes du Laboratoire avec les Ingénieurs Espagnols a permis d'établir que ces apports étaient essentiellement dus au fort vent local du Nord-Est, en provenance de la Région TETOUAN-TANGER, les sédiments étant ensuite remaniés à l'intérieur du Port et à ses abords par l'action des vagues.

CORONEL (CHILI). Colmatage de la partie basse d'un profil littoral.

Le wharf d'embarquement, dont la longueur avait été fixée à pres de 500 m pour atteindre les fonds de 12 metres, n'a pas fait obstacle aux transferts littoraux, comme l'a attesté la pulsation des profils d'estran et des petits fonds voisins.

Par contre, des matériaux d'origines diverses (résidus de chargement, déjections de la mine voisine, etc.) sont venus s'accumuler à l'extrémité du wharf, provoquant l'échouage des navires.

Ainsi, tandis que les sables les plus grossiers transitaient le long de la côte, l'accumulation progressive de matériaux de toute origine, à l'extrémité de l'ouvrage, provoquait un engraissement lent et continu de la partie basse des profils (jusqu'à la cote —12 m environ),

SABLANCEAUX. (ILE DE RE — FRANCE). Extension et pivotement d'une flèche sableuse naturelle.

La liaison ILE de RE/ CONTINENT, par Bacs automoteurs, utilise, depuis de nombreuses années, comme point d'accostage insulaire, l'extrémité de la fleche de SABLANCEAUX.

Ce point d'accostage, qui a dû être déplacé à diverses reprises, en raison de l'ensablement, est, à nouveau, menacé; le trafic a subi plusieurs interruptions pendant l'hiver 1953.

La Mission du Laboratoire a mis en évidence:

1°) — le pivotement lent, mais continu, de la flèche vers le N. W., dû principalement aux grosses houles des régions Ouest ayant pivoté autour du plateau de CHAUVEAU;

2°) — la disparité marquée des stock sédimentaires échelonnés de la dune vers les fonds marins, contredisant la notion, pourtant si répandue, même parmi les techniciens qualifiés, d'un transfert de sables à travers le PERTUIS BRETON.

MONACO. Erosion de la plage du LARVOTTO par un Rip-Current.

La Mission du Laboratoire a procédé à la mesure directe d'un Rip Current qui a provoqué l'érosion, à toute époque, de la côte du LARVOTTO, et continue à entraîner les matériaux les plus légers (sables et graviers) des dépôts artificiels.

De ce fait, les fonds compris entre —5 et —15 se trouvent progressivement remblayés.

SAN ANTONIO (CHILI). Influence d'un cañyon sous-marin perpendiculaire à la côte sur les transferts littoraux de sédiments.

La côte sableuse, sensiblement rectiligne, qui se développe sur 5 km environ vers le Nord, à partir de l'embouchure du RIO MAIPO, s'arrete avant le saillant rocheux du CAP PANUL, en bordure d'un cañyon sous-marin, maintenant inclus en partie dans le port de SAN ANTONIO, dont il emprunte naturellement la passe d'entrée.

On s'est souvent demandé pourquoi les sables ne se déversaient pas dans le cañyon, et de nombreuses hypothèses ont été avancées: retrait des sables vers la haute mer?; courant violent au fond du cañyon?

La Mission d'Observations du Laboratoire a commencé par relever, de facon détaillée, la topographie sous-marine. En même temps, elle observait que le plan de vagues est caractérisé, au voisinage du Môle Sud, par une orientation systématique des crêtes vers le Sud, ayant pour effet de refouler les sédiments et de leur interdire l'accès de la passe d'entrée.

RIVIERE DE CAYENNE (GUYANA FRANCAISE). Propagation de la marée.

Le Laboratoire a procédé à une campagne d'observations hydrographiques et océanographiques sur l'ensemble des côtes de la GUYANE FRANCAISE.

Les observations faites sur la rivière de CAYENNE ont fait ressortir certaines anomalies dans la propagation de la marée:

— durée du courant de flot légèrement supérieure à celle du jusant;

— décalage dans le temps, entre les postes d'observations plus faibles pour les B. M. que pour les P. M.

Ces anomalies s'expliquent d'ailleurs fort bien par la configuration particulière de la rivière.

H 31

RECHERCHES OCEANOGRAPHIQUES AU LARGE DES COTES DE GYANE ET DES BOUCHES DE L'AMAZONE

Par

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Une station océanographique a été créée en 1953 par l'Office de la Recherche Scientifique Outre-Mer en GYANE Française. Elle est pourvue d'un équipement assez complet et d'un bateau de recherches permettant de travailler en haute mer. Les résultats présentés dans cette note ont été obtenus au cours d'une première Croisière effectuée en Octobre 1953 au large de la GYANE et de l'embouchure de l'AMAZONE, jusqu'à 250 milles de la côte environ. Vingt stations profondes ont été réalisées.

En surface l'influence des eaux de l'AMAZONE est particulièrement nette le long de la côte dans une bande large de 50 milles (devant CAYENNE) à 100 milles (3° N), et plus au large par des régions à minimum de salinité.

En profondeur on a particulièrement étudié la zone à fort gradient vertical de densité et dans la partie supérieure de celle-ci la couche présentant verticalement un maximum de salinité. Cette dernière étant très peu épaisse le maximum réel de salinité peut dans certains cas ne pas avoir été obtenu par suite de l'intervalle de profondeur séparant les prélèvements à chaque station. Il semble cependant que les maxima de salinité soient légèrement inférieurs à ceux observés précédemment dans cette région. La structure du

courant équatorial, au moment des mesures dans cette région, est étudiée. L'examen des différentes caratéristiques de la couche de discontinuité, l'étude de la topographie des surfaces σ_t, révèlent une structure assez compliquée, montrant que les conditions au moment des mesures ne sont pas permanentes.

H 32

LA PENETRATION DE L'ULTRAVIOLET DANS LA MER

Par

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Le but de ces recherches est l'étude directe en mer, à diverses profondeurs et dans différentes directions, du rayonnement ultraviolet naturel.

L'appareil est un petit spectrographe à optique de quartz enfermé dans une boite étanche munie d'un hublot de quartz; un filtre (sulfates de Co et Ni) coupe les grandes longueurs d'onde, et des grilles réduisent l'intensité pour les mesures au voisinage de la surface. Les spectres sont enregistrés sur film de 35 mm, qu'un moteur électrique déplace entre chaque pose. L'étalonnage du film est réalisé au moyen d'une source étalon à flourescence.

Les premières mesures faites en Méditerranée, au large de Monaco, en juin et septembre 1953, ont porté essentiellement sur le rayonnement venant d'en haut à la verticale; jusqu'à une profondeur de 50 m on trouve une énergie appréciable de proche ultraviolet. Par temps couvert, la luminance vers le haut décroit exponentiellement avec la profondeur; les valeurs du coefficient d'absorption déduites de plusieurs mesures présentent entre elles un accord satisfaisant et correspondent à une transmission par mètre de l'ordre de 90% pour 4 000 A et 69% pour 3 200 A. Par temps clair, la décroissance au voisinage de la surface est moins rapide, et les courbes du logarithme de la luminance en fonction de la profondeur présentent un coude entre 25 et 30 m, ce qui s'explique par le rôle du rayonnement diffusé du soleil.

Quelques mesures ont été faites également vers le bas et dans la direction horizontale. Par temps couvert, à 10 m de profondeur le rapport du rayonnement venant d'en haut à celui qui arrive horizontalement est de l'ordre de 10, et à celui qui vient d'en bas de l'ordre de 30.

H 33

THE DEPTH OF THE WIND-PRODUCED HOMOGENEOUS LAYER IN THE OCEANS

By
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The homogeneous layer which occurs in the sea is defined by Rossby and Montgomery (1935) as "the really homogeneous shallow surface layer", which is "homogeneous in regard to all its properties". It is presumed to result in the main from the turbulence produced by the wind, but also appears to be affected by secondary sources of turbulence, some of which may be responsible for the dissipation of the layer.

The depth, h, of the wind-produced layer is expressed as a function of the wind speed in the following form:

$$h = K.\text{cosec } L.W_0 - K'.W_0^2$$

where L is the latitude, W_0 the wind speed at the level of the sea surface, and K and K' are constants.

Other effects being neglected, an attempt is made to examine the extent to which the latitudinal zoning of the depth, h, is likely to be disturbed by the variations which occur in wind strengths from place to place. The first and third quartiles of the wind strength frequencies were estimated for 10° rectangles in the Atlantic and Pacific Oceans by 3-month periods. Values of h were computed from the third-quartile wind strengths by means of the expression stated above, the second-order term being neglected, and were plotted on charts and contoured. The first quartile speeds were found to be less than Force 4 for the most part, and were not therefore considered to be of interest.

It seems that although variations in wind strength may give rise to changes in the thickness of the layer in the course of a few days, the layer assumes in general a certain fairly steady thickness, which is presumed to be related to the local wind conditions. It appears that the third quartiles of the wind strength frequencies may be taken as a fair representation of these conditions, in so far as they were responsible for the homogeneous layer, since comparison between observed and calculated depths of the layer shows a broad agreement.

The charts indicate noteworthy departures from the latitudinal zoning of the contours which would occur if the wind speeds were everywhere the same. In Atlantic equatorial regions, for instance, the computed boundary surface of the layer slopes from east to west, as is known to occur in fact. There would also appear to be considerable seasonal changes in the thickness of the layer. Between latitudes 30° to 60°, the diminution of the effect of the wind with increase of latitude is more than balanced by increase in wind strength, so that after a rapid shallowing in lower latitudes, the layer tends to deepen again to about 55° N in the North Atlantic.

It is hoped that the present study may help in the interpretation of the bathythermograph observations which are being widely collected at present.

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H 34

VARIATIONS IN THE SURFACE TENSION OF SEA WATER *IN SITU*

By

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As a contribution to the investigation of the effect of the wind on the sea, trials were made of a method for studying "slicks" on the sea surface. Slicks are the relatively smoother areas of surface which occur in irregular patches or as elongated streaks in rougher areas. They arise as a result of the presence on the sea surface of organic leptopel. Compaction of the film of this material has the effect of depressing the surface tension and damping the ripples, whence comes the typically smooth, oily appearance of the "slicks". Compaction of the film is produced by several agents, one of which is the wind. True slicks are developed by light winds, up to about Force 3, which ripple the surface. With stronger winds they are replaced by a system of streaks believed to be associated with a cellular circulation pattern consisting of helical vortices.

Methods for measuring the depression of surface tension by the leptopelic film have been described, but in a number of cases these involve the collection of samples, which may introduce uncertainty. Our attention was drawn to a method described by Adam (1937), by which measurements can be made directly on the sea surface, and an opportunity was taken for one of us to make trials of the method at Monaco.

The method depends on the fact that since water has a relatively high surface tension, several fatty substances can be found that will just spread against a contaminating film which lowers the surface tension. At the point of very slow spreading the sum of the air-oil

and water-oil tensions must be just less than the air-water tension. The spreading force is given by $\gamma_{aw} - (\gamma_{ao} + \gamma_{wo})$. Solutions were made up, in different concentrations, of small quantities of *n*-dodecyl alcohol in Medicinal Paraffin, which does not spread on a clean water surface, and the spreading force of each solution was determined by the Vertical Film Balance method as described by Harkins (in Weissberger, 1945). The procedure at sea is simple. A drop of each solution in turn is allowed to fall on the sea surface until one of a pair is found which just spreads and the other does not. The behaviour of the drops can be readily observed in light winds. With stronger winds, Force 4 or 5, manipulation is difficult and the drops spread and contract, apparently under the influence of the numerous small waves present.

In the ruffled areas, the depression of surface tension was consistently found to lie between 2 and 3 dynes/cm. In the slicks, higher values were recorded, which on occasions exceeded 22½ dynes/cm. It is thought that in these instances of exceptionally high values, the greater part of the surface contamination may have come from the land.

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H 35

SIMPLIFICATION DE LA TABLE DE TITRATION DE MARTIN KNUDSEN POUR LA DETERMINATION DE LA CHLORINITE DE L'EAU DE MER

Par

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La Table de Titration (2e partie de "Hydrographical Tables", 1901, pp. 23—34) de M. Knudsen permet le calcul de la chlorinité à partir des résultats d'analyse, à la précision de $\pm 0{,}01‰$. Dans sa forme actuelle, elle se prête difficilement aux interpolations par rapport aux paramètres a et α, nécessaires pou obtenir une meilleure précision.

Or, les titrations actuelles sont couramment faites à la précision de $\pm 0{,}005‰$ Cl. Pour que cette précision ne se trouve pas affectée par le calcul, il est indispensable que ce calcul soit fait avec trois décimales exactes.

Cette nécessité nous a conduit à recalculer cette table de manière à l'adapter aux exigences d'une plus grande précision tout en la rendant d'un emploi plus commode.

Dans la nouvelle table, le paramètre α (titre de la solution de nitrate d'argent) se trouve supprimé. Un calcul préliminaire très simple permet, avant d'entrer dans la table, de tenir compte de la valeur exacte de ce paramètre.

Cette suppression du paramètre α entraine les trois importantes conséquences suivantes:

1) La table est établie pour les variations d'un seul parametre,

a (lecture à la burette). Elle se trouve ainsi considérablement simplifiée. Dans sa forme actuelle elle tient en une demie page.

2) Le calcul de la chlorinité à l'aide de la nouvelle table devient possible quelque soit le titre de la solution de nitrate d'argent employée dans la titration, alors que la table de Knudsen imposait à ce titre des limites très serrées. Nous sommes ainsi libérés des fastidieuses et fréquentes opérations de réajoustements du titre de la solution de nitrate d'argent, jusqu'ici absolument indispensables.

3) Enfin, la possibilité de choisir librement la valeur du titre de la solution de nitrate d'argent a pour conséquence d'agrandir sensiblement et presque de doubler l'intervalle d'utilisation de la burette classique de Knudsen. On utilisera des solutions concentrées pour les eaux de mer à forte salinité (Mediterranée) et des solutions faiblement concentrées pour les eaux de mer à faible salinité. Le titre de la solution doit être choisi de manière que la titration de l'eau normale demeure possible avec la burette utilisée. Avec une burette graduée de 17 à 21, on peut ainsi titrer des échantillons de chlorinité allant de 16 à 23 $^{0}/_{00}$. La précision ne se trouve pas affectée par le recours à cet artifice.

La table est calculée avec trois décimales pour toutes les valeurs du paramètre *a* de 0 à 23,9. L'intervalle uniforme de variation de ce paramètre est de 0,1 et les interpolations sont immédiates.

La nouvelle table permet donc un calcul rapide de la chlorinité avec une précision égale à celle de l'analyse.

Elle a été publiée au Journal du Conseil Permanent International pour l'Exploration de la Mer, Vol. 19, No. 3, 1954.

H 36.1

UNITA' DI MISURA NELLE RICERCHE CHIMICO-FISICHE-TALASSOGRAFICHE

Di

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Il Comitato, costituito dai professori Bjorn Helland-Hansen, J. P. Jacobsen e Thomas G. Thompson, incaricati di esaminare e di proporre un'unificazione dei metodi di ricerca chimico-fisico-talassografica e delle unità da usare per esprimere i risultati ottenuti, ha presentato ancora nel settembre 1939 all'Assemblea Generale dell'Associazione per l'Oceanografia Fisica (AOF) di Washington D. C. un rapporto, reso noto, alcuni anni or sono, nel n° 9/1948 delle Pubblicazioni Scientifiche dell'A. O. F. Questo Istituto Talassografico ha creduto opportuno, ancora nel 1941, di presentare in una tabella riassuntiva le unità ritenute le meglio idonee per l'indicazione quantitativa delle diverse caratteristiche fisico-chimiche delle acque marine.

Tenuto conto delle varie proposte fatte da autori diversi, e che vengono riassunte nel loro contenuto essenziale, viene presentata una nuova tabella con le unità di uso più comune, e delle quali si propone l'adozione nella elaborazione dei risultati ottenuti delle ricerche oceanografiche.

Molti oceanografi sono propensi di esprimere le concentrazioni dei singoli componenti che caratterizzano un determinato corpo d'acqua marina, in g-atomo/litro o kg., anzichè nella forma percentuale g/litro o kg. oppure μg/litro. I due sistemi g-atomo o grammo-pesosono tutti e due corretti, però l'espressione percentuale peso/peso oppure peso/volume è preferita, specialmente dai non chimici e soprattutto dai biologi, in quanto rende meglio l'idea della concentrazione considerata.

Pertanto, se viene adottata definitivamente l'espressione grammo-atomo o grammo-molecolare, si ritiene opportuna l'aggiunta anche del dato numerico esprimente la concentrazione percentuale. Il denominatore della frazione si riferisce naturalmente al volume dell'acqua ambiente; per la clorinità e la salinità è ormai fuori di ogni discussione il riferimento al chilogrammo e non al litro; analogo riferimento (peso/peso) dovrebbe valere pure per i costituenti fondamentali (Na, K, Ca, Mg, Cl^-, SO_4^{--}, HCO_3^-, Br^-). Per le concentrazioni dei cosidetti elementi nutritivi e specialmente per la serie oligodinamica è preferibile invece il riferimento peso/volume oppure volume/volume per i gas disciolti, perchè nei metodi analitici il campione esaminato viene misurato sempre in volume.

H 37.1

ANNUAL CYCLES OF BEACH EROSION AT WALTAIR ON BAY OF BENGAL

By

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With data obtained from repeated measurements of beach profiles at two points along the Waltair beach, the nature and extent of influence of wave-height, currents, engineering operations and sea-level on the beach configuration have been examined and cycles are established for the two points which represent two distinct beach environments. It has been found that a major cut is experienced in the beach between the period May and September, when the waves are high and the dominant currents are from the South-West. The presence of a break-water south of the beach plays an important part in the cutting of the beach, since waves are continually refracted by striking the breakwater. This is especially true in the South-West monsoon when South-West currents prevail. No such refraction is found during the North-East monsoon. Changes in sea-level are found to be of negligible import in influencing the beach configaration. It has also been found that beaches with submerged rocks and stacks are cut more rapidly than beaches free from such obstructions, especially during the season of high-waves. This is attributed to the increased turbulence of the waves when they strike the rocks, thus putting more sand into suspension, which is likely to be influenced by the long-shore currents and off-shore circulation.

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H 37.2

THE CONCRETIONS NEAR CONTINENTAL SHELF OFF VISAKHAPATNAM AREA

By

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The occurrance of concretions in the sea floor sediments off Visakhapatnam is a significant fact revealed during the oceanographic investigations, recently conducted by the Andhra University. The zone of concretions extends from depth of 70 fathoms to 100 fathoms and corresponds to a distance of about 20 to 25 miles from the coast of Visakhapatnam. The concretions form a dominant constituent of the sediments imparting course and gritty aspects to them, the other constituents being small material, sand, clay and silt. Though they are first recognised near about 40 fathoms, they are somewhat sparse in distribution and insignificant in size, till they occur in greater force and in larger dimensions between 70 and 100 fathoms. The concretions range in size from submicroscopic dimensions to 2 to 3 mm. Their shape varies from ovoid, spherical to irregular, sometimes being aggregates of smaller concretions. They are coloured grey, greenish, black, creamy-white, white and with shades of brown. They have sometimes a nucleus of a fine sand grain or a fragment of shell or any other material around which deposition has taken place. The surface of the concretions is smooth and shining in some cases while it is rough, pitted and dull in other cases. They easily dissolve in acid, the essential constituent being calcium carbonate. Some amount of iron is also present. Phosphorous present in the concretions can be estimated. The mechanical analysis of the sediments and chemical analysis of the concretions are carried out with a view to understand the genetic and depositional history of the concretions.

The occurrence of excessive shell material in proximity to the zone of concretions, and sometimes overlapping it, appears to suggest that factors which are destructive to the growth of shell organisms arre conductive to the development of concretions and that in a sense, these two processes are complementary. The causes leading to the formation of concretions such as the salinity, pH values, temperature structure and presence of suspended materials are all under investigations.

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H 37.3

LE PLATEAU CONTINENTAL EST MEDITERRANEEN

Par

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J'ai l'honneur de vous présenter un résumé des premiers résultats d'un examen sommaire fait sur le plateau continental levantin.

La recherche en est à ses premiers pas; il serait donc prématuré de formuler déjà des résultats.

En ce qui concerne notre recherche méme, nous tenons à signaler qu'elle n'était qu'un premier essai qui n'a considéré la question que du côté géomorphologique. Dans l'avenir il faudra envisager le problème sous un angle plus large englobant tous les domaines de la recherche océanographique. Nous sommes convaincus qu'une telle recherche jetera de la lumière sur le problème compliqué du climat au pléistocène au Levant auquel, d'après tous les symtômes manifestés et abstraction faite des mouvements eustatiques évidents le long de notre côte, les glaciations quaternaires n'ont apporté aucun changement tangible.

I — *QUALITE DE LA COTE*. Notre côte est de type pacifique simple, perturbé par des mouvements tectoniques. Elle est divisée en divers segments qui sont en harmonie avec l'évolution des plis levantins.

Les événements tectoniques successifs sont d'une importance secondaire. La côte palestinienne est assujettie aux perturbations érythréennes (cassures dirigées NW — SE), mais la côte libano-syrienne aux failles méridionales et équatoriales.

2 — *QUALITE DU PLATEAU CONTINENTAL* — Notre plateau continental est le résultat de la combinaison des mouvements tectoniques et eustatiques, qui dirigent l'activité exodynamique relativement faible des vagues. Les conditions de facteurs exodynamiques de la mer et du continent ne stimulent pas une grande action. Dans les fragments maturés mêmes, l'activité tectonique trouble d'une façon prépondérante les forces exogéniques. Cette intervention est trés évidente dans les fragments septentrionaux du plateau, généralement embryonnaires (même de moins d'un km de large).

Les plateaux adjacents (l'égyptien et le turc) se distinguent nettement, à tous points de vue, du levantin.

3 — *LES MOUVEMENTS EUSTATIQUES.* Parmi les événements quaternaires de la côte, les fluctuations glacio-eustatiques sont les plus tangibles. La faune du Mugharet el Wad, sur le Carmel, et la distribution des industries préhistoriques le long de la plaine côtiere en témoignent. Une bonne concordance regne entre les niveaux quaternaires des côtes méditerranéenes occidentales et orientales. L'étude de la morphologie sous-marine continentale nous donne une idée de la vitesse extraordinaire des mouvements eusta tiques ingressifs (vitesse envisagée sur une échelle géologique, bien entendu).

4 — *MOUVEMENTS TECTONIQUES.* Leur existence ne peut être niée. Les alluvions du Nil semblent en être un des principaux facteurs. Mais les perturbations érythréennes et celles du même genre jouent un rôle important. En tout cas, ces mouvements comparés à l'activité eustatique sont infiniment freinés, par leurs élans ou dimensions, dans le cadre quaternaire, bien entendu.

5 — *L'AGE DU PLATEAU CONTINENTAL DU GOLFE DE HAIFA.* Pendant le néogene, des mouvements orogéniques et diastrophiques (érythréens, par exemple) ont crée le grand *Golfe d'Esdrélon.* Depuislors, le plateau continental du Golfe de Haifa (l'unique golfe israélien!) alla constamment se développant. Des forces semblables, mais de dimensions réduites, ont contribué à la formation du plateau continental israélien.

6 — *LE PROBLEME DES GRAVIERS.* Les fluctuations glacio-eustatiques qui ont atteint au quaternaire ca. —100 et + 100 m. au-dessous et au-dessus du niveau actuel, peuvent parfaitement expliquer l'alternance entre les graviers et autres dépôts alluviaux. Des graviers furent déposés sur le plateau continental loin du rivage actuel. Leur existence à ces endroits qui sont soumis de nos jours à l'alluvionnement sableux, n'implique nullement un climat plus humide que celui de maintenant.

7 — *DUNES CALCIFIEES* (KURKAR). L'étude du plateau continental jette de la lumiere sur l'origine du kurkar et sur les facteurs qui ont contribué à sa formation. Il est probable qu'il faut signaler parmi ceux-ci, l'influence de l'eau de la mer venue en contact aves les dunes.

8 — *TOPOGRAPHIE SOUS-MARINE.* Le plateau continental contient, en dehors des traces du temps regressives (graviers, kurlar, etc.) des traces d'anciens littoraux (gisements de lumachelle, coraux, etc.). L'étude qui sera prochainement entreprise, offrira une bonne contribution à l'étude océanographique, en général.

9 — *LE RIVAGE ACTUEL.* Le rivage actuel nous indique que nous nous trouvons dans une phase ingressive. Cependant nous trouvons des traces qui indiqueraient une récente phase regressive.

H 38

ON THE VARIATION OF WATER TEMPERATURE DUE TO THE PASSAGE OF TYPHOON

By

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Typhoons (tropical cyclones) which are mighty meteorological disturbances give rise to various hydrographical phenomena in the waters such as wind-waves, swell, turbulent mixing in the stratified waters, upwelling, overturning of watermasses, stormy currents, storm-surges, seiches, the variation of water temperature and turbidity. Basing on the observed data in the waters adjacent to Japan, the author studied the variation of the water temperature due to the passage of typhoons.

In general, the variations of water temperature in such cases are mostly due to the turbulent mixing and the horizontal transport of water masses.

When the Muroto Typhoon (Pc = 911.9 mb.) attacked Japan on 21 Sept. 1934, the coastal water temperature adjacent to Japan showed a marked variation. During the approach of a typhoon the water temperature rises gradually and consequently it attains a maximum about 2 or 3 days before the passage. Then it drops down to its minimum within 3 days after the passage.

In case of another severe typhoon (Pc = 896 mb.) of 5—6 Oct. 1949, the «Kaiyōmaru No. 4» (Japanese Hydrographic Dept.) carried out the oceanographic and meteorological observations in the seas south of Shiono-Misaki (about 24°—25°N, 135°—136°E) through the heart of this typhoon at the risk of the lives of crew, and

obtained the results that the air temperature and surface water temperature show their maxima at about 32 hours before the passage of the typhoon centre.

In the third case, during the passage of the typhoon (Pc = 933 mb.) of August 27, 1942, which landed on the western Japan, we observed the currents by an Ekman current meter and measured the water temperature, salinity etc. in the Bungo Strait (the western entrance of Seto Naikai) in the period from 25 August to 2 September. As the typhoon approaches nearer in this case, the north-going current flowing into the Inland Sea (Seto Naikai) became stronger and reversely the outflow (South-going current) from the Inland Sea increased after its passage of typhoon centre. After the passage the stratification of water masses was completely destroyed by the effect of turbulent mixing due to the gales and the water temperature showed a marked rise of + 1° — + 4°C compared to that before the passage. This perhaps proves the effect due to the continued inflow of the warm water of Kuroshio (i.e. advectional effect).

In the flood period (from H. W. to about 1 hour after it) temrature maximum with the velocity maximum of the north-going flood current 1—2 kn. at 1—2 hours preceding H. W. and in the ebb period the south-going current maximum with the velocity of 1—2,5 kn. and with the temperature max. at about L. W. were shown and the phenomena were repeated in conformity with the semidiurnal tidal current.

Cancelling them, the inflow effect by the integrated velocity in the cross sectional area of Bungo Strait and the consequent temperature rise by the horizontal transport were proved. Locating the boundary between the inland and the oceanic waters, the variation of water temperature is remarkable in this case by the horizontal transport.

H 39

ON THE SIGNIFICANCE OF NICKEL AND COBALT IN DEEP-SEA DEPOSITS

By

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The presence of nickel in deep-sea sediments has been known for many years, and its ultimate source has generally been assumed to be cosmic material. Recently there has been a greatly increased interest in this problem amongst astronomers and it has been pointed out by Opik that there is a similarity between van de Hulst's figure for the space density of zodiacal light cloud of primordial dust and that required to account for the nickel content of deep-sea clays. The same author has also suggested that the maxima of nickel occurring in deep-sea cores may be due to the passage of the solar system through small galactic nebula, and that zodiacal light and the nickel of deep-sea clays are produced mainly by primordial dust of the solar system spiralling towards the sun in orbits which are nearly circular.

In view of these astronomical theories, confirmation about the cosmic origin of nickel is clearly necessary. In order to do this nickel, cobalt and copper have been determined by radioactivation methods in a representative number of deep-sea floor samples from the Atlantic, Indian and Pacific Oceans, as well as on oceanic rocks, manganese nodules and stony meteorites. As the ratios of Ni: Co, Ni: Cu, Cu: Co are distinctly different in deep-sea sediments to those found in meteorites, it would seem that there is little significant contribution of meteoritic material to deep-sea sediments unless some remarkable differential behaviour of the three elements has taken place.

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